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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

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THE MARINER 2 MISSION

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1 of 109

PREFACE

The Planet Venus

During the centuries, man has accumulated relatively little indisputable scientific information about the planet Venus. Astronomers have been hampered in their attempts to investigate the planet because it is continually covered by a dense blanket of clouds.

Our closest planetary neighbor, Venus is in orbit between the Earth and the Sun. Traveling at 78,300 miles per hour, it has a sidereal period (or year) of 225 days. Its average distance from the Sun is 67,200,000 miles.

Venus has been referred to as the Earth's twin. It has an estimated diameter of 7800 miles, as compared to 7926 miles for the Earth. Also, it is believed to have a mass and gravitational field similar to that of Earth.

Because it was not observed throughout the night, but appeared in morning and evening skies, ancient astronomers thought Venus to be two bright stars.

During its nearly circular orbit, Venus comes within 26,300,000 miles of the Earth at closest approach or inferior conjunction. At superior conjunction, or the point at which the Earth and Venus are at opposite sides of the Sun, it is 162,000,000 miles away.

Inferior conjunction occurs every 584 days, thus providing a launch opportunity for Earth-based space probes each 19 months. As Venus approached inferior conjunction in August 1962, Mariner 2 was launched to intercept the planet nearly 4 months later, and to attempt to gather scientific data about the mystery planet and transmit it back to earth.

One of the puzzling features is the changeable dark and light markings that appear on Venus' cloud layer. Scientists have speculated that these markings could be breaks in the cloud cover, but there has been little agreement as yet.

Another outstanding characteristic of Venus is its brightness. Because it is close to the Sun and has a reflective cloud layer, Venus is the third brightest object in our sky, after the Sun and Moon. Its reflectivity is measured about 60 percent, as compared to 7 percent for our Moon.

Spectrographic studies (identification of materials by presence of absorptive features, lines, or bands in the spectrum) seem to indicate that Venus contains carbon dioxide and nitrogen, but probably little free oxygen or water vapor. Measurements taken in the infrared region of the electromagnetic spectrum indicate that temperatures of minus 38°F exist somewhere in the atmosphere, probably at or somewhere near the top of the visible clouds. The microwave regions, however, show temperature of as much as 800°F at, or somewhere near, the surface.

Scientists are still not in agreement as to the altitude from which these temperatures emanate. Indeed, there is one theory that Venusian ionosphere, with thousands of times the electron density of the Earth, gives the impression that the planet is extremely hot. If this theory is correct, this electron layer could easily mislead scientists measuring temperatures of Venus from Earth. This theory now appears to have been disproven by independent evidence for high temperatures in the lower atmosphere, and for the existence of a second, lower cloud layer. This second layer is probably composed of hydrocarbons, whose presence in the atmosphere would help explain the maintenance of the high surface temperatures. The Mariner experiments will provide further evidence to help scientists decide between the various theories and will yield a more detailed mapping of the cloud and surface temperatures than is possible from the vicinity of the Earth.

Recent radar measurements suggest that Venus rotates at a slow rate, perhaps once every 225 days, which is the length of the Venusian year. This would mean that Venus always keeps the same side facing the Sun, much the same as our Moon keeps the same side facing the Earth.

CONTENTS

TABLES

FIGURES

SECTION I

THE MARINER 2 MISSION

Mariner 2, the second of a series of spacecraft designed and developed for planetary exploration by the Jet Propulsion Laboratory of California Institute of Technology, was launched on August 27, 1962, at 1:53:13:9 a.m. (EST) from the Atlantic Missile Range, Cape Canaveral, Florida, by the National Aeronautics and Space Administration.

Mariner 1, launched at 4:21 a.m. (EST) on July 22 from the Atlantic Missile Range was destroyed by the Range Safety Officer after approximately 290 seconds of flight because of a deviation from the planned flight path.

Measures were taken to correct the difficulties experienced in the Mariner 1 launch, including a more rigorous checkout of the Atlas rate beacon and revision of the data-editing equation. The data-editing equation is designed as a guard against acceptance of faulty data by the ground guidance equipment.

The Mariner 2 spacecraft (Fig. 1), carrying six scientific experiments, was identical to Mariner 1 and had the same mission: to fly by the planet Venus and perform two scientific experiments -- close-range infrared and microwave measurements -- and to communicate this information over an interplanetary distance of 36,000,000 miles back to Earth. Four scientific experiments were performed during the flight, and in the vicinity of Venus, to collect and transmit information on interplanetary phenomena.

The flight time for Mariner 2 was approximately 109 days. The over-all flight distance was approximately 180 million miles. Mariner passed closer to Venus than any previous Earth-launched spacecraft and was within the desired miss distance.

NASA assigned two launches for Mariner in 1962 because of the inherent difficulty of an interplanetary mission, and to take advantage of the period that year during which Venus will be close to Earth. The next launch opportunity for Venus will not occur for 19 months (in 1964).

Mariner tracking and communication was provided by JPL's Deep Space Instrumentation Facility, with permanent stations at Goldstone, California; Woomera, Australia; and Johannesburg, South Africa; and mobile stations at Cape Canaveral and near the permanent station at Johannesburg. These stations transmitted data received from the spacecraft to JPL's Space Flight Operations Center for correlation by an IBM 7090 computer system.

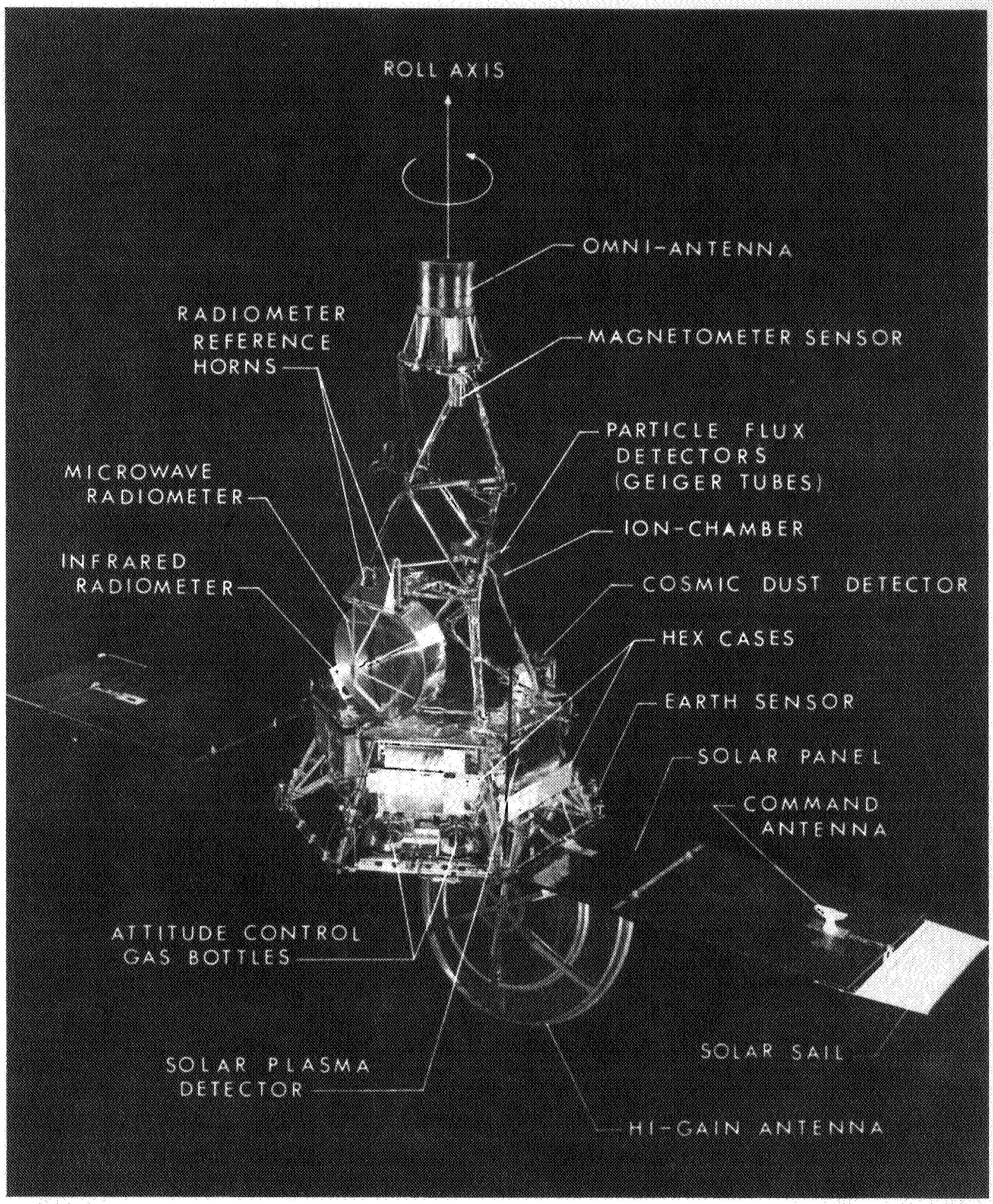


Figure 1. This photograph of Mariner 2 shows some of the scientific and engineering equipment aboard the spacecraft. Mariner 2 in its cruise position is 16.5 feet in span, about 12 feet in height, and weighs 448 pounds

A. SPACECRAFT DESCRIPTION

The Mariner 2 weighed 448 pounds and, in the launch position, was 5 feet in diameter at the base and 9 feet, 11 inches in height. In the cruise position, with solar panels and high-gain antenna extended, it was 16.5 feet across in span and 11 feet, 11 inches in height (Table 1).

Table 1. *Mariner 2* data

Launch vehicle	*Atlas-Agena B*
Dimensions (launch vehicle)	
Total height (with *Mariner* spacecraft plus shroud)	100 plus feet
Atlas	66 feet
Agena B	22 feet
Mariner (with shroud)	12 feet
Dimensions (*Mariner*)	
In launch position (panels folded):	
Diameter	5 feet
Height	9 feet 11 inches
In cruise position (panels unfolded):	
Span	16 feet 6 inches
Height	11 feet 11 inches
Weight (*Mariner* 2)	
Structure	77 pounds
Solar panels	48 pounds
Electronics	146 pounds
Propulsion	32 pounds
Launch-backup battery	33 pounds
Miscellaneous equipment	71 pounds
Scientific experiments	41 pounds
Gross weight	448 pounds

The design was a variation of the hexagonal concept used for the JPL Ranger series. The hexagonal framework base housed a liquid-fuel rocket motor for trajectory correction, and six modules containing the attitude control system, electronic circuitry for the scientific experiments, power supply, battery and charger, data encoder and command subsystem, digital computer and sequencer, and radio transmitter and receiver. Sun sensors and attitude control jets were mounted on the exterior of the base hexagon.

A tubular superstructure extended upward from the base hexagon. Scientific experiments were attached to this framework. An omnidirectional antenna was mounted at the peak of the superstructure (Fig. 2). A parabolic, high-gain antenna (Fig. 3) was hinge-mounted below the base hexagon. Two solar panels were also hinged to the base hexagon. They fold up alongside the spacecraft during launch, parking orbit, and injection phases, and are unfolded like butterfly wings when the craft is in space. A command antenna for receiving transmissions from Earth was mounted on one of the panels.

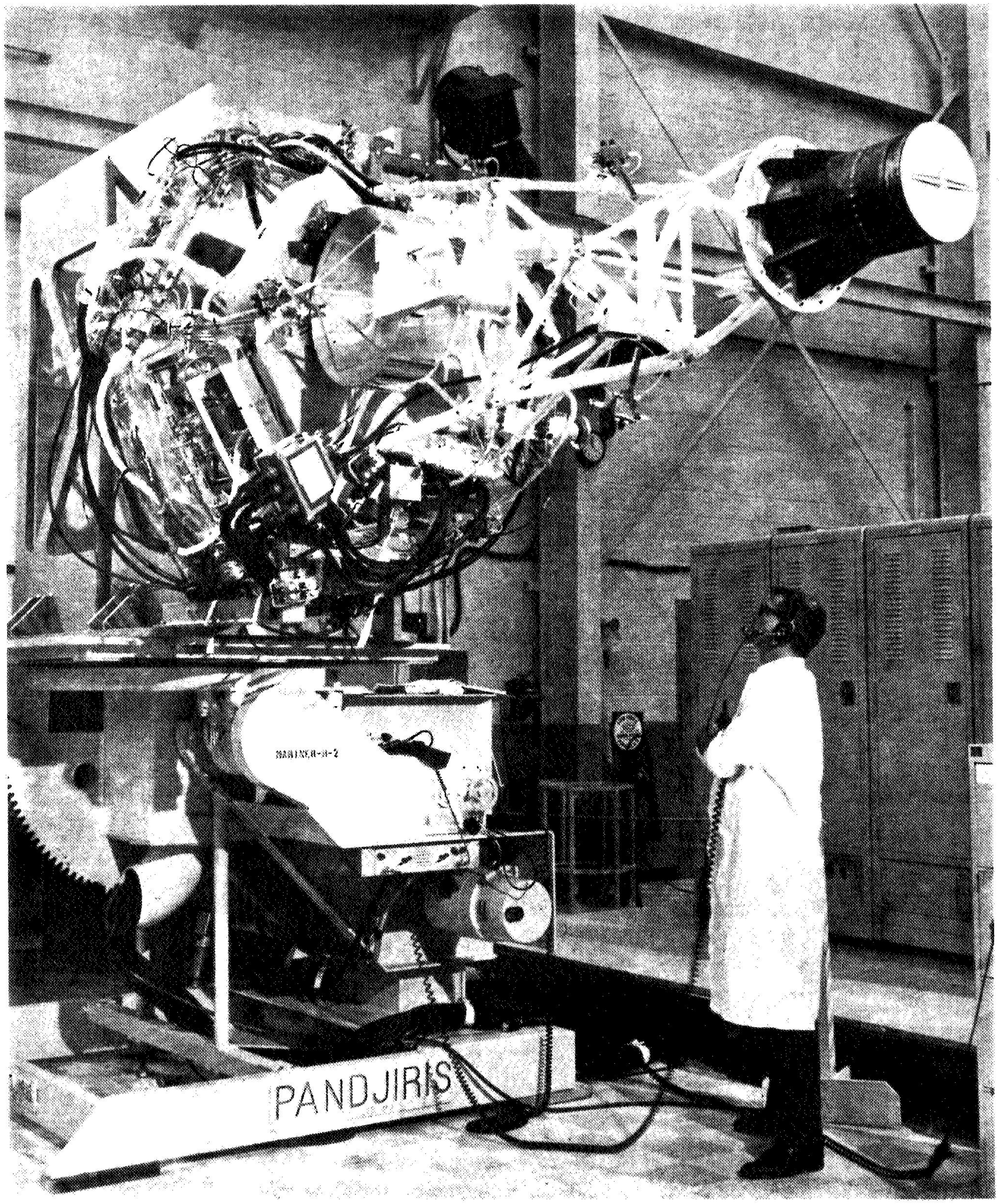


Figure 2. Mariner 2 spacecraft on test stand at Jet Propulsion Laboratory. Solar panels that convert sunlight to electricity are not attached to spacecraft for this test. Note omnidirectional antenna at extreme right

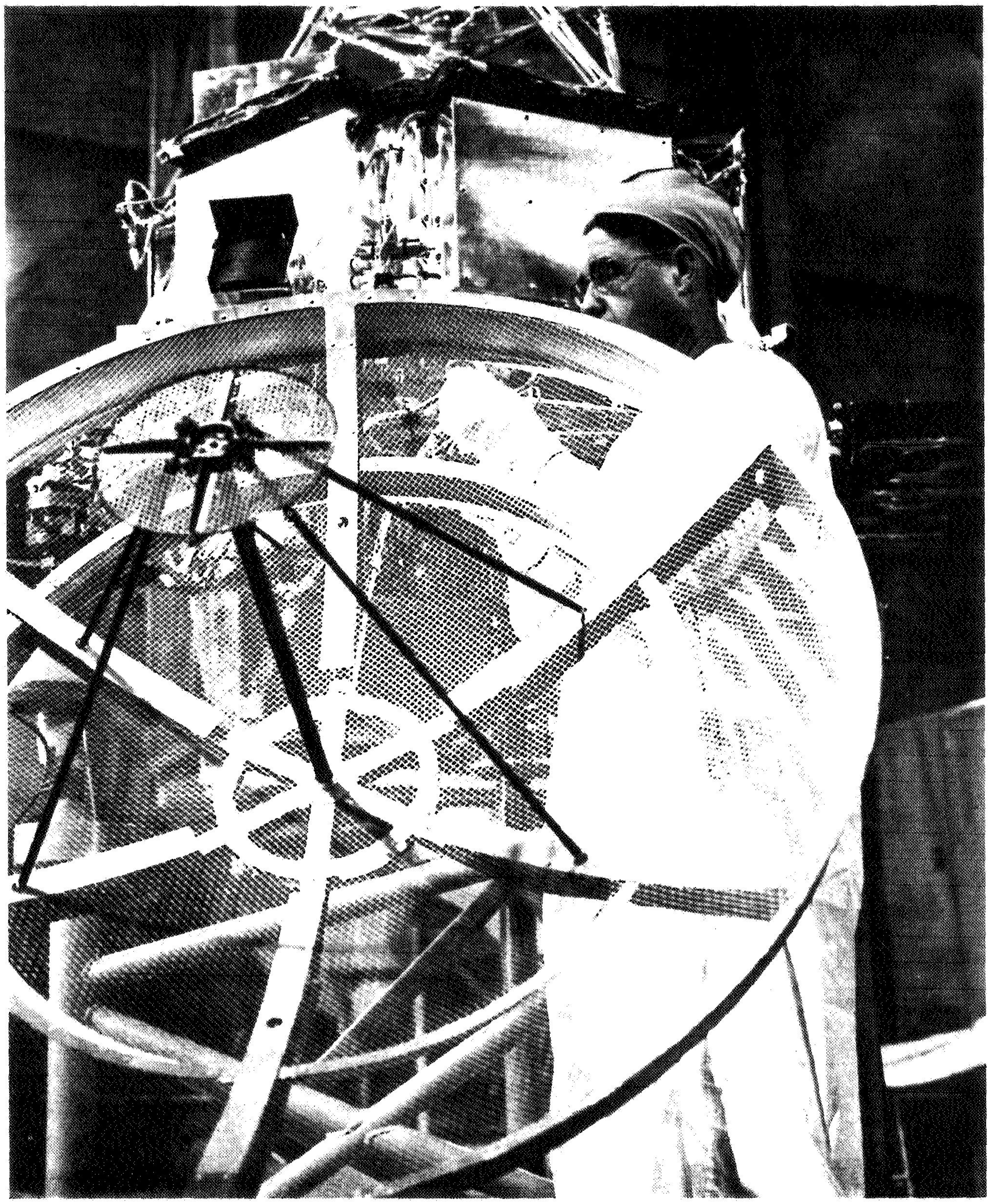


Figure 3. Technician makes adjustment on Mariner 2 spacecraft at Jet Propulsion Laboratory. In foreground is dish-shaped, high-gain antenna capable of transmitting data from spacecraft to Earth over interplanetary distances

The solar panels (Figs. 4 and 5) contain 9800 solar cells in 27 square feet of area. They collected energy from the Sun and converted it into electrical power at a minimum of 148 watts and a maximum of 222 watts. The amount of power available from the panels was expected to increase slightly during the mission due to the increased intensity of the Sun. Each solar cell had a protective glass filter that reduced the amount of heat absorbed from the Sun, but does not interfere with the energy conversion process. The glass covers filter out the Sun's ultraviolet and infrared radiation which would produce heat but not electrical energy.

The power subsystem converted electricity from the solar panels and battery to 50-volt ac, 2400-cps; 26-volt ac, 400-cps; and 25.8- to 33.3volt dc power.

Prior to deployment of the solar panels, power was supplied by a 33.3-pound, silver-zinc, rechargeable battery with a capacity of 1000 watt-hours. The recharge capability was used to meet the long-term power requirements of the Venus mission. The battery supplied power directly for switching and sharing peak loads with the solar panels and also supplied power during trajectory correction when the panels were not directed at the Sun.

Two-way communication aboard the Mariner 2 was supplied by the receiver/transmitter, two transmitting antennas: the omnidirectional and high-gain antennas; and the command antenna for receiving instructions from Earth. The spacecraft transmitting power was 3 watts.

The high-gain antenna was hinged and equipped with a drive mechanism allowing it to be pointed at the Earth on command. An Earth sensor was mounted on the antenna yoke near the rim of the high-gain, dish-shaped antenna to search for and keep the antenna pointed at the Earth.

Stabilization of the spacecraft for yaw, pitch, and roll was provided by ten cold gas jets mounted in four locations, fed by two titanium bottles containing 4.3 pounds of nitrogen gas pressurized to 3500 pounds per square inch. The jets were linked by logic circuitry to three gyros in the attitude control subsystem, to the Earth sensor on the parabolic antenna and to six Sun sensors mounted on the spacecraft frame and on the back of the two solar panels.

The four primary Sun sensors were mounted on four of the six legs of the hexagon, and the two secondary sensors on the backs of the solar panels. These were light-sensitive diodes which inform the attitude control system -- gas jets and gyros -- when they see the Sun. The attitude control system responded to these signals by turning the spacecraft and pointing the longitudinal or roll axis toward the Sun. Torquing of the spacecraft for these maneuvers was provided by the cold gas jets fed by the nitrogen gas regulated to 15 pounds per square inch pressure. Enough nitrogen was provided to operate the gas jets to maintain attitude control for a minimum of 200 days.

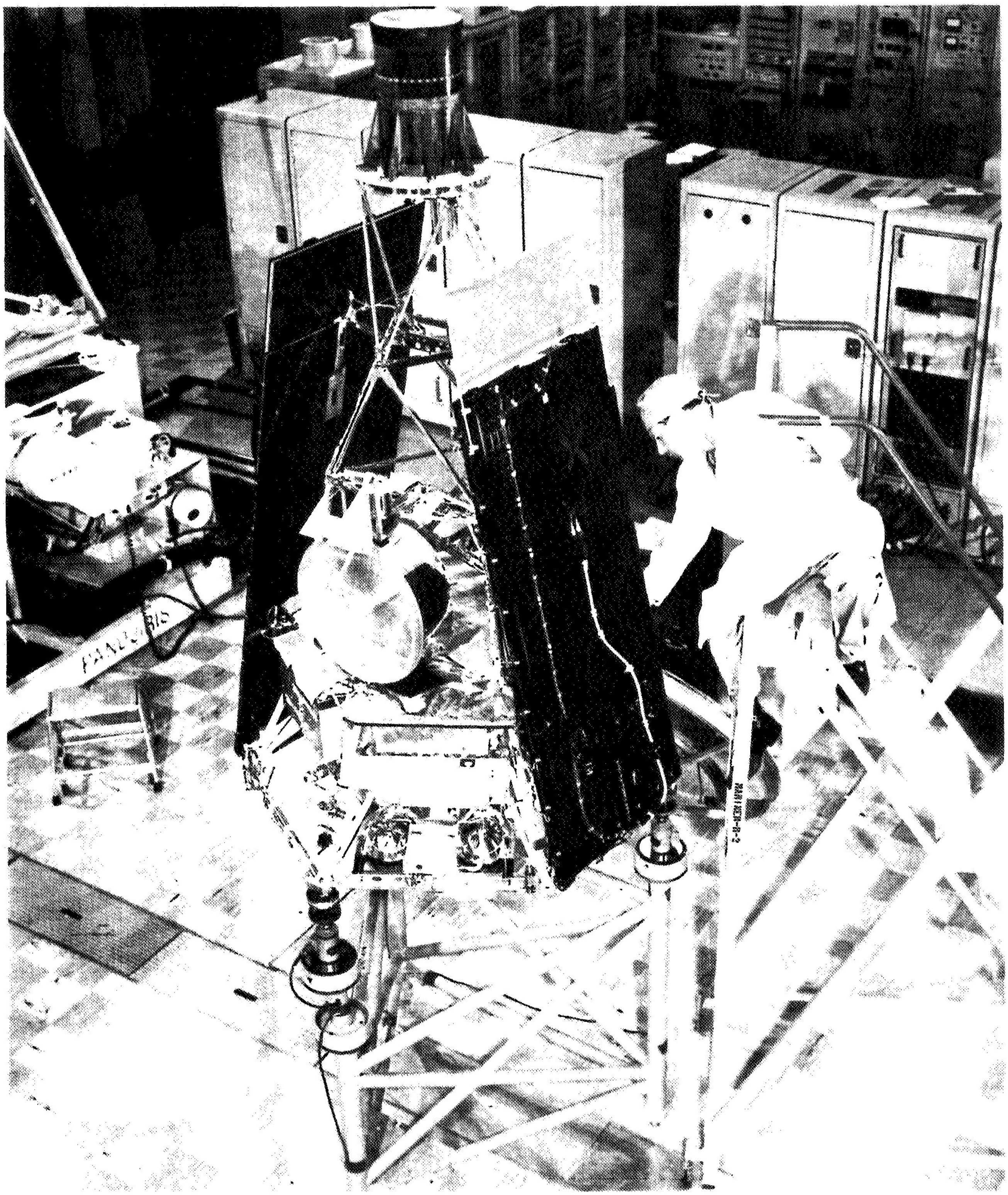


Figure 4. Mariner 2 spacecraft shown in launch position with solar panels folded. After launch, panels are extended, spacecraft is oriented toward Sun and solar cells on panels convert sunlight to electricity. Plastic extension on panel, right, compensates for additional segment on left panel

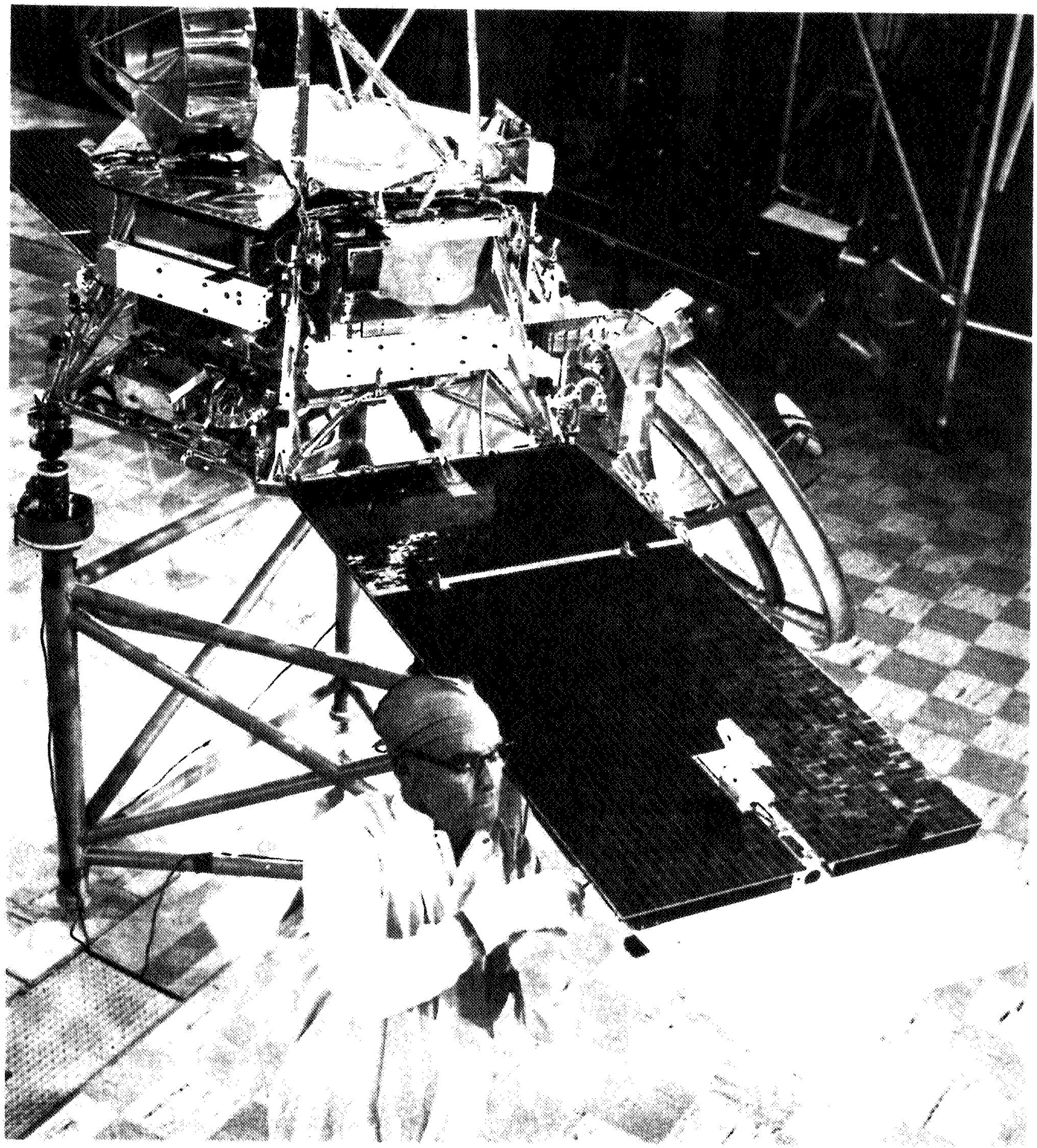


Figure 5. Technician adjusts solar panel on Mariner 2 spacecraft at Jet Propulsion Laboratory. Solar cells on panel convert sunlight to electricity

Computation for the subsystems and the issuance of commands was a function of the digital central computer and sequencer (CC&S). All events of the spacecraft were activated in three CC&S sequences. The launch sequence controlled events from launch through the cruise mode. The midcourse propulsion sequence controlled the midcourse trajectory correction maneuver. The encounter sequence provided required commands for data collection in the vicinity of Venus.

The CC&S provided the basic timing for the spacecraft subsystems. This time base was supplied by a crystal-controlled oscillator in the CC&S operating at 307.2 kilocycles. This frequency was divided down to 38.4 kilocycles for timing in the power subsystem, and divided again to 2400 and 400 cycles per second for use by various subsystems. The control oscillator provided the basic "counting" rate for the CC&S to determine issuance of commands at the right time in the three sequences.

The subsystems clustered around the base of the spacecraft were insulated from the Sun's heat by a shield covered with layers of aluminum-coated plastic film. At the bottom of the spacecraft, just below the subsystem modules, was a second temperature control shield. It prevented too rapid loss of heat into space, which would make the required temperatures difficult to maintain. The two shields form a sandwich that helped to minimize the heat-control problem.

Temperature control of the attitude control subsystem was provided by louvers actuated by coiled bimetallic strips. The strips act as coil springs that expand and contract as they heat and cool. This mechanical action opens and closes the louvers. The louvers were vertical on the face of the attitude control box and regulate the amount of heat flowing into space.

Paint patterns, aluminum sheet, thin gold plate, and polished aluminum surfaces were used on Mariner 2 for passive control of internal temperatures. These surfaces control both the amount of internal heat dissipated into space and the amount of solar heat reflected away, allowing the establishment of temperature limits. The patterns were determined from a testing of a temperature control model, which was subjected to the variations of temperature anticipated in the Venus mission in a space simulation chamber at JPL.

Communication with the spacecraft was in digital form. The command subsystem aboard the Mariner decoded incoming digital commands and sent them to the designated subsystems. Data from engineering and scientific sources were encoded to digital form for transmission to Earth.

Synchronizing pulses were spaced at regular intervals between the data signals from Mariner 2. Ground-based receiving equipment generates identical pulses and matches them with the pulses from the spacecraft. This reference determined the location of the data signals, allowing receiving equipment to separate data signals from noise.

Six scientific experiments were carried aboard Mariner 2. Four of these were designed to collect information in space and in the vicinity of Venus. The other two provided information solely on Venus and operated only as Mariner passed the planet. The experiments were:

(1) Microwave radiometer experiment to measure temperature distribution on the planet's surface.

(2) Infrared radiometer experiment to provide information on the distribution of thermal energy in the planet's atmosphere.

(3) Magnetometer experiment to determine the three mutually perpendicular components of the magnetic field in interplanetary space between Earth and Venus, and in the vicinity of Venus at planetary encounter.

(4) Charged particle experiment to detect the distribution, variations, and energies of electrically charged particles in space and in the vicinity of Venus, and the rate at which charged particles lose energy.

(5) Plasma experiment to obtain information on the extent, variations in, and the mechanism of the solar corona.

(6) Micrometerorite experiment to measure the density of cosmic dust particles which exist in interplanetary space and in the vicinity of Venus.

The microwave radiometer was mechanized to scan Venus during the fly-by. The infrared experiment was attached to the rim of the dish-shaped microwave device and scanned with the larger instrument.

B. MISSION DESCRIPTION

Project management for the Venus mission was assigned to the Jet Propulsion Laboratory of California Institute of Technology by the National Aeronautics and Space Administration. This assignment included responsibility for the spacecraft system and space flight operations. The Marshall Space Flight Center had the responsibility for providing the launch vehicle, with the support of the USAF Space Systems Division. General Dynamics Astronautics provided the Atlas D first Stage, Lockheed Missiles and Space Company the Agena B second stage.

Management personnel associated with the Mariner Project were: Fred D. Kochendorfer, Mariner Program Chief, NASA Headquarters; D. L. Forsythe, Agena Program Chief for NASA; Robert J. Parks, Planetary Program Director for JPL; J. N. James, JPL Mariner Project Manager; W. A. Collier, JPL Assistant Project Manager; Dan Schneiderman, JPL Spacecraft System Manager; Friedrich Duerr, MSFC Launch Vehicle Systems Manager; Major J. G. Albert, Mariner Launch Vehicle Director for AFSSD; and H. T. Luskin, Director for NASA Programs, Lockheed Missiles and Space Company.

Several factors made the Venus mission difficult: the long flight time, subjection of the spacecraft to a prolonged variation in temperature, unknown radiation effects in interplanetary space, transmission of a considerable amount of information over an extreme range, and a complex trajectory problem.

Mariner 2 was launched by an Atlas D-Agena B booster vehicle (Fig. 6). The Atlas and the Agena boosted the spacecraft to an altitude of 115 statute miles.

Mariner 2 used the parking orbit technique, which is a means by which the geometry imposed on a Venus launch by the location of the Atlantic Missile Range at Cape Canaveral, Florida, is corrected by using the second-stage rocket as a mobile launching platform in space.

During the launch phase, the Mariner spacecraft was protected against aerodynamic heating by a shroud. After Atlas cutoff, approximately 5 minutes after liftoff, the shroud was jettisoned by eight spring-loaded bolts which shoved it ahead of the vehicle. At almost the same time, the Agena B separated from the Atlas. The Agena B then pitched down from an attitude almost 15 degrees above the local horizon to almost level with the local horizon.

In this horizontal attitude, the Agena B fired for the first time and burned for almost 1 minute to reach orbital speed of about 18,000 miles per hour. After this burning time, Agena B shut down and coasted in a parking orbit for more than 13 minutes until it reached the optimum point in time and space to fire for the second time.

The second Agena B burn injected the Agena B and Mariner, still as one unit, on an escape trajectory at 25,700 miles per hour. Injection occurred approximately over Ascension Island in the South Atlantic Ocean, about 25 minutes after launch.

A little more than 2 minutes after second burn cutoff, or injection, Mariner 2 was separated from Agena, again by spring-loaded bolts. Agena then yawed (turned sideways) 140 degrees in the local horizontal plane and performed a retro maneuver which reduced the velocity and moved the Agena into a different trajectory. Propulsion for the retro maneuver was provided by ejecting the unused fuel on the Agena through small jets. The retro maneuver served two purposes:

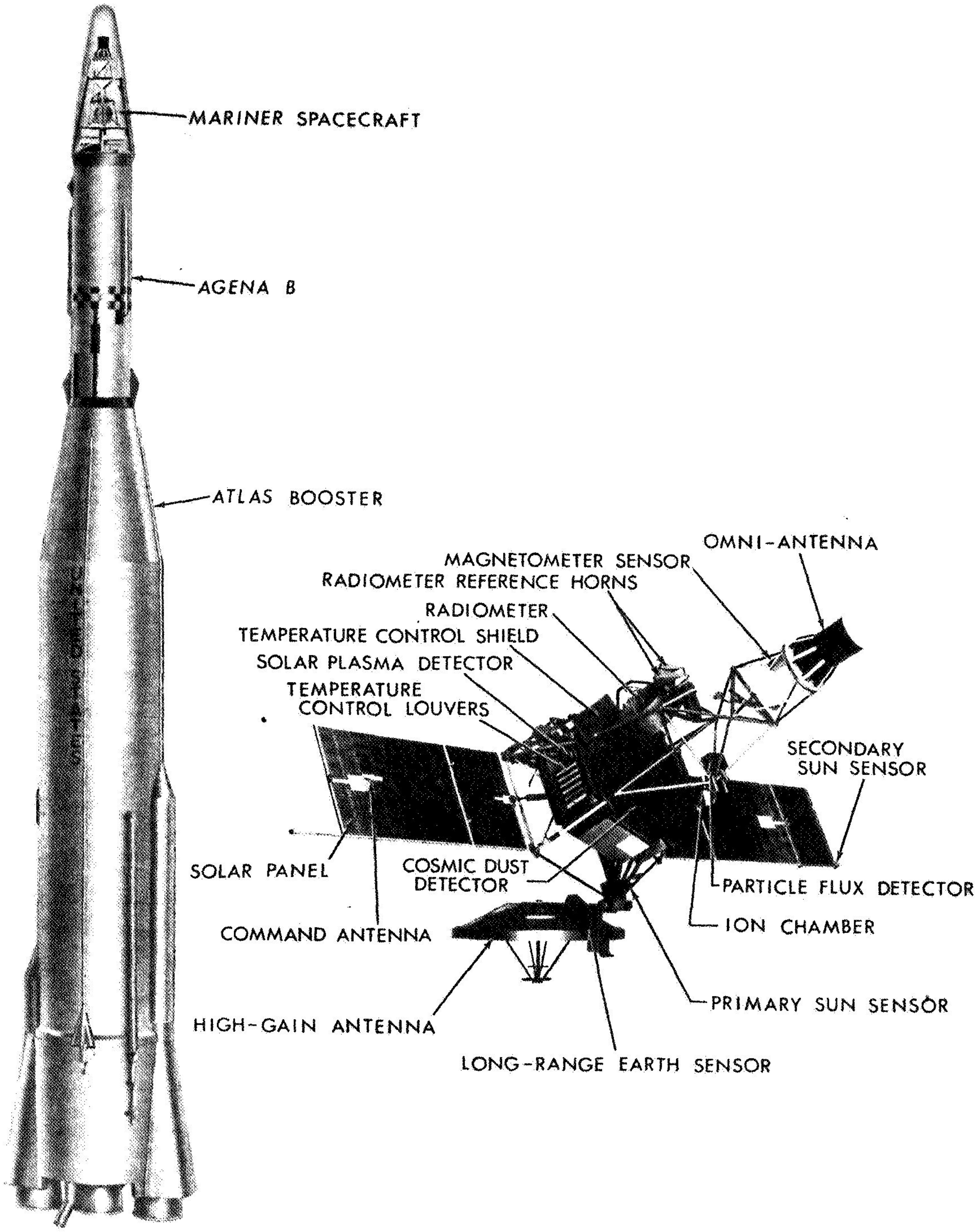


Figure 6. On left of this composite photo of scale models, the Mariner 2 spacecraft can be seen in its launch position atop the Atlas-Agena B booster vehicle. The spacecraft with solar panels extended in cruise mode is shown at right. Principal components and instrumentation are indicated

(1) It prevented the unsterilized Agena from impacting Venus.

(2) If Agena B follows Mariner too closely, the spacecraft optical sensors might mistake reflected sunlight from Agena for the Sun or Earth and confuse its acquisition program.

Mariner 2 was now on a trajectory that would take it within 376, 000 kilometers of Venus. The omnidirectional antenna was working and radiating the radio transmitter's full 3 watts of power. Before and during launch, the transmitter had been kept at about 1. 1 watts. This lower power is required during the period the launch vehicle passes through a critical area between 150, 000 and 250, 000 feet, where a tendency exists for devices using high voltage to arc over and damage themselves; hence, the transmitter is kept at reduced power until this area is passed.

Mariner 2 was designed to conduct the following sequence of events on its flight to Venus:

The first command was issued by the CC&S 44 minutes after launch. Explosive pin pullers holding the solar panels and the radiometer in their launch positions were detonated to allow the spring-loaded solar panels to open and assume their cruise position, and to free the radiometer to scan Venus as the spacecraft passes the planet. Although the radiometer will not function until Venus encounter, it was convenient to unlock it at this point.

At launch plus 60 minutes, the CC&S turned on the attitude control system and the Sun acquisition mode began. The Sun sensors, linked to the valves controlling the gas jets, moved the spacecraft about until its longitudinal axis was pointed at the Sun, thus aligning the solar panels with the Sun. Both the gyros and the Sun sensors can activate the gas jet valves. A back-up radio command capability was provided to initiate the CC&S function and Sun acquisition.

In order to conserve gas, the attitude control system permitted a pointing error toward the Sun of 1 degree, or 0. 5 degree on each side of dead on. The mixing network in the attitude control system was calibrated to keep Mariner slowly swinging through this 1 degree of arc pointed at the Sun. The swing took approximately 60 minutes. As Mariner neared the 0. 5-degree limit on one side, the sensors signaled the gas jets and they fired again. This process was repeated through the effective life of Mariner. It was calculated that the gas jets would fire 1/50 of a second each 60 minutes to keep the spacecraft's solar panels pointed at the Sun. When the Sun was acquired, the gyros were turned off to avoid having an unnecessary power demand and to conserve the life of the gyros.

The Sun acquisition process was designed to take less than 30 minutes. When it was completed, the secondary Sun sensors on the backs of the solar panels were turned off to avoid having light from the Earth confuse them.

As soon as the solar panels were locked on the Sun, the power system began drawing electric power from the panels. The battery would now only supply power in the event of a peak demand that the panels could not handle. Excess power from the panels would be utilized to recharge the battery.

The next event initiated by the CC&S was the acquisition of Earth by the high-gain, directional antenna, 167 hours (7 days) after launch. The Earth sensor used to align the antenna was so sensitive that it would not operate properly if used earlier. Once again, a radio command capability was provided to back up the initiation of this event.

During Earth acquisition, the spacecraft maintained its lock on the Sun, but with its high-gain, directional antenna pointed at a preset angle, it rolled on its long axis and started to look for the Earth. It did this by means of the three-section photo-multiplier-tube-operated Earth sensor mounted on and aligned with the high-gain antenna. During the roll, the Earth sensor sees the Earth and informs the gas jets. The jets fire to keep the Earth in view of the sensor and thus lock onto the Earth. The sensor had a lens system to magnify the Earth image.

The spacecraft now is stabilized on two axes -- the solar panel-Sun axis and the Earth-directional antenna axis. There was some danger that the Earth sensor, during its search for the Earth, may see the Moon and lock onto that body, but telemetry later would inform Earth stations if this had occurred, and the Goldstone station had the ability to send an override command to the attitude control system to tell it to look again for the Earth. If this were not sufficient, the station could have sent a hinge override command to change the hinge angle and then order another roll search. When the Earth was acquired, the transmitter stopped transmitting on the omni-antenna and was switched to the high-gain antenna.

A rise in signal strength indicated that Earth acquisition had been achieved by the high-gain antenna. Positive proof is afforded by analysis of telemetry to determine the angle of the antenna hinge.

With Sun and Earth acquisition achieved, Mariner 2 was now in its cruise mode, which continued until time for the midcourse trajectory correction maneuver.

Tracking data collected by the DSIF stations was sent to JPL and fed into the 7090 computer system. The computer compared the actual trajectory of the Mariner with the course required to yield a 10,000-mile fly-by. If guidance errors before injection have put Mariner off the optimum trajectory, the computer provides the necessary data to command the spacecraft to alter its trajectory. This involves commands for roll, pitch, and motor burn. Roll and pitch point the spacecraft for the trajectory correction. Motor burn provides the additional velocity required to change direction of travel.

Midcourse correction (Fig. 7) of the Mariner 2 trajectory occurred on September 4, 1962. The first command from Goldstone gave the direction and amount of roll required, the second gave the direction and amount of pitch needed, and the third the amount of velocity increment needed. This data was stored in the CC&S until Goldstone transmitted a "go" command.

Prior to this command, Goldstone ordered Mariner's transmitter to switch from the directional antenna at the base of the craft to the omnidirectional antenna mounted at the peak of the superstructure.

Commands preprogrammed in the CC&S for the midcourse sequence initiated the following events:

(1) The Earth sensor, mounted on the dish-shaped antenna, was turned off.

(2) The hinge-mounted directional antenna moved out of the path of the midcourse motor's exhaust. (The gyros had been turned on an hour earlier to warm up.) During the maneuver, the gyros informed the attitude control subsystem of the rate of pitch and roll as they occurred for reference against the orders from Earth. A pulse-balanced accelerometer was turned on to provide acceleration rates during motor burn to the CC&S. Each pulse from the accelerometer represented a velocity increment of 0.03 meter per second.

The roll maneuver requires a maximum of 12 minutes of time, including 2 minutes of settling time, and the pitch maneuver requires a maximum of 22 minutes. When these events were completed, the midcourse motor was turned on and burned for the commanded time. As the attitude control gas jets are not powerful enough to maintain the stability of the spacecraft during the propulsion phase of the midcourse maneuver, movable jet vanes extending into the exhaust of the midcourse motor control the attitude of the spacecraft during this period.

The jet vanes were controlled by an autopilot subsystem in the attitude control system that functions only during the midcourse maneuver. The autopilot accepts information from the gyros to direct the thrust of the motor through the spacecraft's center of gravity to stabilize the craft.

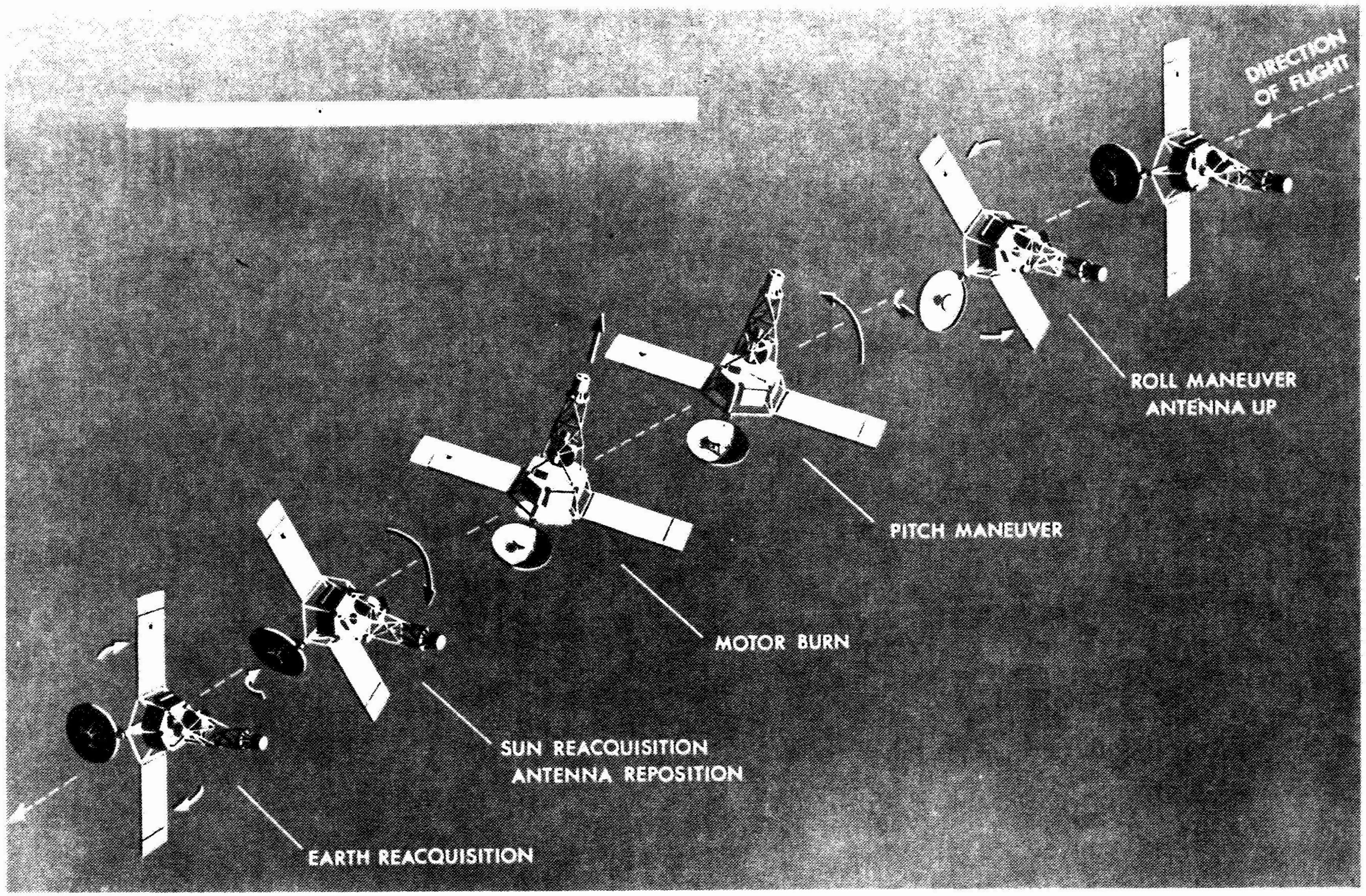


Figure 7. Artist's sketch shows Mariner 2 executing a typical trajectory correction command sent to it by the JPL Goldstone (Calif.) tracking station. The high-gain antenna moves up so it will not be damaged by the midcourse motor flame. The spacecraft then rolls, pitches, receives a velocity increment from the mid-course motor, attains the desired Venus trajectory, repositions its antenna, and then reacquires its cruise attitude by locking its solar panels on the Sun and its high-gain antenna on the Earth

21

The liquid monopropellant midcourse motor weighed,with fuel and the nitrogen pressure gas system, 37.3 pounds. Hydrazine fuel was held in a rubber bladder inside the propellant tank (a doorknob-shaped container). On the command to fire, nitrogen under 3000 pounds of pressure per square inch in its supply tank, was admitted inside the propellant tank and squeezed the rubber bladder, forcing the fuel into a combustion chamber.

Hydrazine is a monopropellant fuel and requires ignition to start the combustion process. A starting fluid, in this case nitrogen tetroxide, is admitted into the combustion chamber by means of a pressurized cartridge and causes ignition. A catalyst, consisting of aluminum oxide pellets, is stored in the combustion chamber to control the combustion process. Burning stops when the valves turn off nitrogen pressure and flow of fuel.

The midcourse motor is so precise that it can burn in bursts of as little as 2/10 second, and can increase velocity by as little as 7/10 foot per second, or as much as 200 feet per second. It has a thrust of 50 pounds for a maximum of 57 seconds.

After the midcourse maneuver put Mariner 2 on the desired trajectory for Venus encounter, the spacecraft again went through the Sun and Earth acquisition modes.

During midcourse maneuver, Mariner transmitted through the omni-antenna. When the Earth was acquired, the transmitter was switched to the high-gain directional antenna. This antenna was used for the duration of the flight.

Mariner 2 continued in the cruise mode until planet encounter. During this period, tracking data from the three permanent DSIF stations was sent to JPL where the 7090 computer system refined the earlier calculations for planet encounter made at launch.

The CC&S was programmed to begin the encounter sequence 10 hours in advance of encounter. This allows time for calibration of the planetary encounter scientific instruments before encounter in the event that the spacecraft might fail to perform the midcourse trajectory correction. If this should occur, then the predicted encounter time could vary in time up to 10 hours. Under any circumstances, the tracking-computer system had the capability of predicting the time of encounter to within 15 minutes.

At the 10-hour period, the CC&S would switch out the engineering data sources, leaving on the interplanetary science experiments, and turn on the two planetary experiments. During the fly-by, only scientific data will be collected and transmitted.

The radiometer was designed to begin with a fast-search wide scan until Venus is sensed and then go into a slow scan. The planetary experiments collected data on Venus for 1/2 hour as Mariner 2 passes the planet.

The encounter mode of transmission -- scientific data only -- will continue 56.7 hours after encounter. At the end of this period, the CC&S will switch on the engineering data sources and, again in the cruise mode, both engineering and interplanetary scientific data will be transmitted. Both the start and stop of the encounter mode of operation was capable of being performed by a backup radio ground command.

C. SCIENTIFIC EXPERIMENTS

The Mariner 2 spacecraft carried six scientific experiments (Table 2), representing the efforts of scientists at nine institutions: The Army Ordnance Missile Command, the California Institute of Technology, the Goddard Space Flight Center of NASA, Harvard College Observatory, the Jet Propulsion Laboratory, the Massachusetts Institute of Technology, the State University of Iowa, the State University of Nevada, and the University of California at Berkeley.

Table 2. *Mariner 2* scientific experiments

Experiments	Description	Experimenters
Microwave radiometer	Determine the temperature of the planet surface and details concerning its atmosphere	Dr. A. H. Barrett, Massachusetts Institute of Technology; D. E. Jones, JPL; Dr. J. Copeland, Army Ordnance Missile Command; Dr. A. E. Lilley, Harvard College Observatory
Infrared radiometer	Determine any fine structure of the cloud layer	Dr. L. D. Kaplan, JPL and University of Nevada; Dr. G. Neugebauer, JPL; Dr. C. Sagan, University of California, Berkeley
Magnetometer	Measure changes in the planetary and interplanetary magnetic fields	P. J. Coleman, NASA; Dr. L. Davis, Caltech; Dr. E. J. Smith, JPL; Dr. C. P. Sonett, NASA
Ion chamber and particle flux detector	Measure charged-particle intensity and distribution in interplanetary space and in the vicinity of the planet Venus	Dr. H. R. Anderson, JPL; Dr. H. V. Neher, Caltech; Dr. J. Van Allen, State University of Iowa
Cosmic dust detector	Measure the density and direction of cosmic dust	W. M. Alexander, NASA Goddard Space Flight Center
Solar plasma spectrometer	Measure the intensity of low-energy protons from the Sun	M. Neugebauer, and Dr. C. W. Snyder, JPL

The two planetary experiments were a microwave radiometer and an infrared radiometer. They were to operate during a period of 30 minutes and at distances ranging from approximately 23,400 miles to 14,000 miles as Mariner approaches Venus. These radiometers obtained information about the planet's temperature and atmosphere.

The other experiments made scientific measurements during the cruise through interplanetary space and in the near vicinity of Venus. They were: a magnetometer; charged-particle detectors, including an ionization chamber and several Geiger-Müeller counters; a cosmic dust detector; and a solar plasma detector.

One of the important considerations in choosing these experiments was the compromise between what scientists would like to measure during the mission and what was technologically possible. For example, of the 448 pounds that could be placed in a Venus trajectory, only about 41 pounds could be allocated to scientific experiments.

Another restricting factor was time. Venus is in a favorable position for investigation by a Mariner-type spacecraft only during a period of a few weeks every 19 months.

In addition, scientists asked Mariner 2 to convert electrical power from the sunlight, report its findings from as far as 36, 000, 000 miles and, although sensitive and unattended, remain in precise working order for 3 to 5 months in the hostile void of space.

Although Venus is our closest planetary neighbor, there are many things about it that remain a mystery. Several theories concerning the nature of its atmosphere and surface have been advanced. One of the missions of Mariner 2 was to make several scientific measurements of the planet which may substantiate one of these theories, or call for the formulation of a new one.

During the cruise and encounter of Venus, Mariner 2 telemetered information to Earth. As the sensors of the six experiments receivedinformation, they fed it to a data conditioning system (DCS), which was located in one of the modules in the hexagonal base of the spacecraft. The DCS prepared information for transmission to Earth in the form of a digital code.

Since all of the data collected by Mariner 2 would not be transmitted at the same time, an electronic clock was built into the DCS. This clock controlled the equipment so that the receiver "listens" to one experiment at a time for about 1 second. After 20.16 seconds, the DCS switches off the scientific data and then the telemetry system sent spacecraft engineering data for 16.8 seconds. This cycle was continued during the cruise in interplanetary space.

When the spacecraft was switched to the encounter mode, however, the spacecraft devoted its telemetry system to the full-time transmission of scientific information from its six experiments.

The integration of the scientific experiments and the generation of a number of the experiments were carried out at JPL under the direction of Dr. M. Eimer. JPL project scientist was R. C. Wyckoff. J. S. Martin was responsible for the engineering of scientific experiments.

1. Microwave Radiometer

This experiment should help to resolve two vital questions about Venus:

(1) What is the atmosphere like?
(2) What is the temperature of the surface?

As Mariner 2 flies past Venus, the microwave radiometer will scan the planetary disk to detect electromagnetic radiation at two wavelengths: 13.5 and 19 millimeters. Earth-based observations have shown a tendency for the "brightness temperature" of the planet to decrease from about 600°K to about 300°K as the measurement wavelength decreases from centimeter to millimeter values, and it is important that this phenomenon should be verified. This variation in apparent temperature with microwave wavelength has led scientists to postulate the existence of a number of models for the planet's atmospheric structure and surface temperature.

Based upon recent evaluation of data taken near 8000 Å, the most probable models are those predicting a high surface temperature coupled with a cooler absorbing atmosphere. Much of the 13.5-millimeter radiation should then originate in the atmosphere, with the 19-millimeter radiation arising primarily from near the hard surface of the planet. Measurements of the temperature difference between the 13.5- and 19-millimeter values, and the variation in this difference obtained as the approximately half-light, half-dark planetary disk is scanned, should allow scientists to deduce a great deal regarding the gross properties of the planet's atmosphere when compared with the data from the Mariner infrared radiometer experiment.

Since the 19-millimeter wavelength radiation from the planet should be comparatively unaffected by the atmospheric constituents, it should be possible to "see" the surface with a geometrical resolution of more than 2 orders of magnitude better than can be obtained at present from the Earth. Although obviously not of photographic quality, this data should nevertheless yield a large amount of information regarding large-scale features of the surface of this cloud-covered planet.

In direct contrast to the cool atmosphere-hot surface models are the several models postulating that the high-centimeter "temperatures" arise from some mechanism occurring above the planet's surface. Hence, the actual surface temperature may be much cooler than 600 or 700°K.

If the source of the high temperature is above the surface, a "limb-brightening" effect is predicted at the shorter wavelength. Because the thickness of the radiating layer increases as the limb or edge of the planet is approached, the effective temperature will also increase.

The cool atmosphere-hot surface models, however, predict a decrease in effective temperature as the limb is approached, or a "limb-darkening" effect. Limb darkening is thought to result from the shielding effect of the cooler atmosphere as it prevents some of the radiation from the hot surface from escaping into space -- an effect which increases with the growing thickness of the shielding layer as the limb is approached.

The microwave radiometer was mounted on the hexagonal base of the Mariner spacecraft. Both wavelengths were detected by a parabolic antenna that measured 20 inches in diameter and 3 inches in depth.

At 10 hours before Venus encounter, the radiometer was turned on. Driven by an electric motor, it started a scanning or nodding motion of 120 degrees at the rate of 1 degree per second. The microwave antenna was only capable of moving in a nodding motion. Lateral movement was provided by the motion of the spacecraft across the face of the planet. When its signals determined that it had acquired the planet, the DCS sent a command to slow the scan rate to 1/10 degree per second.

In order to confine its attention to the planet's disk, a special command system has been built into the DCS. Whenever the radiometer indicates that it has reached the limb and is about to look out into space, the DCS reverses the direction of the scan.

In this mode, it scanned Venus for about 30 minutes. Since the spacecraft was going roughly in the direction of the Sun, the radiometer first scanned part of the dark side of Venus and then part of the sunlit side.

As the radiated microwave energy was collected by the parabolic antenna, it was focused onto a receiving horn located opposite the face of the antenna on a quadripod. The energy from both wavelengths traveled down the two hollow legs (wave guides) of the quadripod.

Two reference horns located on top of the antenna were matched to receive the same two microwave bands as the parabolic antenna. These horns point at an angle of 60 degrees away from the axis of the antenna and, consequently, are always looking at empty space.

The signals from the antenna and the reference horns were alternated or chopped electronically. Then they are sent to a crystal, video-type receiver located behind the antenna. Thus, this receiver measured the difference between the signals from Venus and the reference signals from space. This information was then telemetered to Earth.

The microwave radiometer weighed 23.8 pounds, and required 3.5 watts of power when operating and 8.9 watts during calibration. The calibration sequences were automatically initiated by the DCS a number of times during the mission.

2. Infrared Radiometer

This radiometer was a companion experiment to the microwave radiometer. As the Mariner spacecraft flew past Venus, simultaneous measurements from the two experiments enabled scientists to get a better idea of the temperature and atmospheric conditions of the planet.

The infrared radiometer was rigidly attached to the microwave antenna (Fig. 8). In this way, both scanned the same surface areas of Venus.

The infrared radiometer experiment operated in the 8- to 9- and the 10- to 10.8-micron wavelength regions of the electromagnetic spectrum.

Measurements from Earth in these two wavelengths indicate temperatures below zero. It is not clear to scientists whether all of this radiation comes from the tops of the clouds, or whether some of it emanates from the atmosphere or planetary surface.

The close approach of Mariner 2 to Venus may enable scientists to measure some of the finer details of the atmosphere. This measurement will primarily involve determining if there are any "breaks" in the cloud cover and, if so, the amount of heat that escapes through into space. For many years, some astronomers have been able to occasionally see some kind of markings on Venus' cloud cover that change with no apparent regularity, leaving their nature in doubt.

If these markings are indeed cloud breaks, they will stand out with greater contrast in the infrared region than if observed in the visible part of the spectrum. If the radiant energy detected by this experiment comes from the cloud top and there are no breaks, then the temperatures obtained at both infrared wavelengths will follow a similar pattern. If there are breaks in the clouds, a substantial difference will be detected between measurements at the two wavelengths.

The reason for this difference is that in the 8- to 9-micron region, the atmosphere is transparent (except for clouds). In the 10- to 10.8-micron region, the lower atmosphere is hidden by the presence of carbon dioxide. Through a cloud break, the former would penetrate to a much lower point in the atmosphere. By a comparison of temperatures from both regions, combined wtih microwave data, scientists will have a more detailed picture of conditions on Venus.

The infrared radiometer was 6 inches long and 2 inches wide. It weighs 2.7 pounds and consumes 2 watts of power. It contains two optical sensors, one of which scans the surface of Venus while the other obtains reference readings from space. The latter is aimed at an angle of 45 degrees away from the planetary scanner.

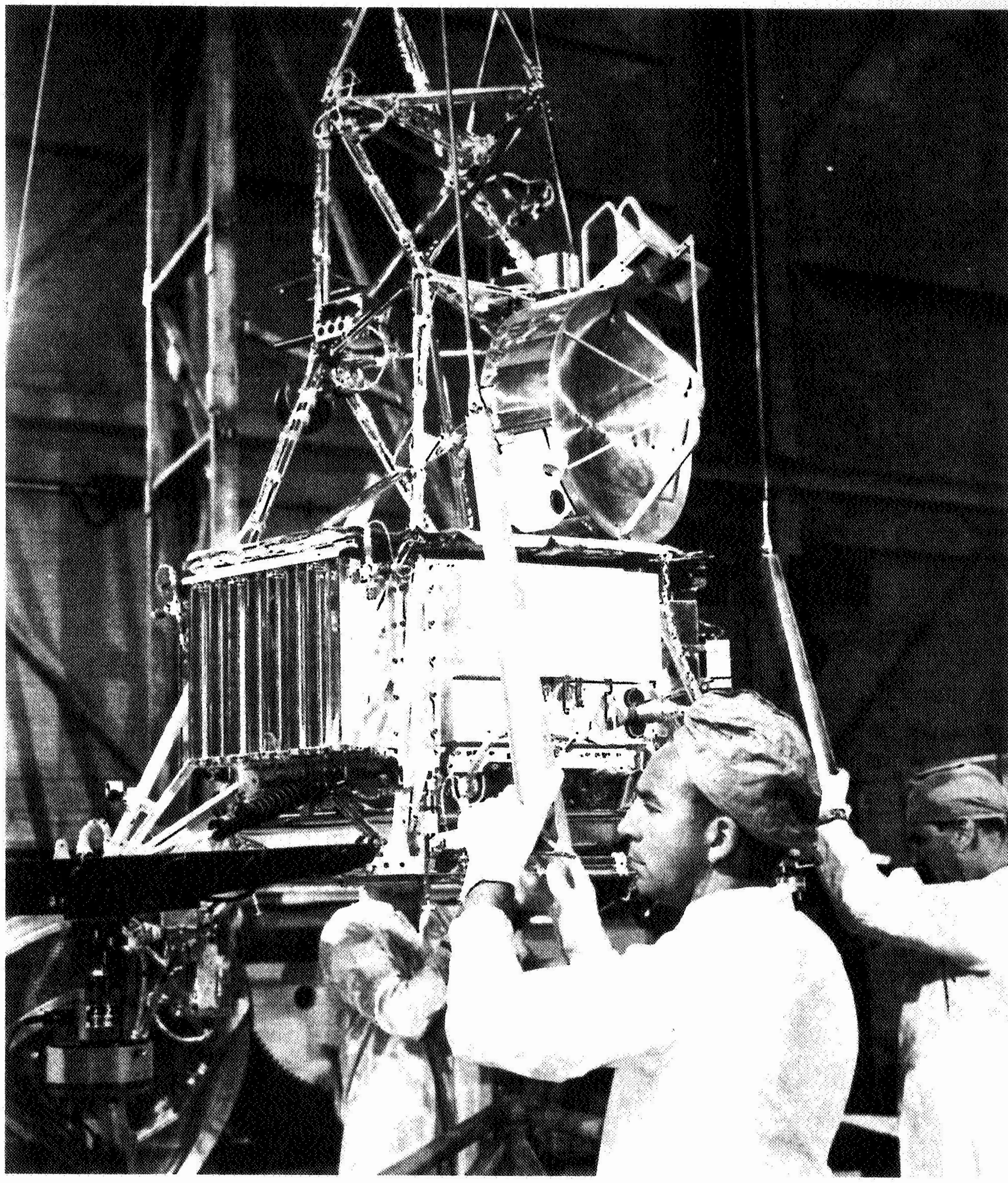


Figure 8. Technicians attach cable to Mariner 2 spacecraft during testing. Note circular microwave radiometer above head of technician in foreground. White object on rim of dish is infrared radiometer. Horns at top of dish are part of reference and calibration systems for radiometers

Radiation from Venus was collected by two f/2.4 optical systems with 3-inch focal lengths. As the infrared energy enters the optical system, it first passes through a rotating disk with two apertures. These were positioned so that the two sensing devices can alternately see Venus and empty space. The infrared beam was chopped in this way at the rate of 20 cycles per second.

After the beam passes the disk, it is split by a dichroic filter into the two wavelength regions. A second pair of filters further refines these wavelengths before they reach the radiometer's sensing devices: two thermistor bolometers, which are sensitive to infrared energy. The electrical output from these detectors was amplified and sent to the DCS for processing and retransmission to Earth.

3. Magnetometer

The magnetometer aboard Mariner 2 was designed to measure the strength and direction of interplanetary and Venusian magnetic fields.

Many scientists believe that the magnetic field of a planet is due to a fluid motion in its interior. If such a Venusian field exists, then it could be detected as Mariner 2 approached the planet. This would depend, of course, on the strength of the field and the distance of Mariner at encounter. Also, the trajectory of Mariner permits the measurement of interplanetary magnetic fields and any variation with respect to time and distance from the Sun.

Present theories of magnetohydrodynamics -- the study of the relation between the motion of charged particles and the magnetic field which surrounds them -- say that the plasma which flows away from the Sun should drag with it the local solar magnetic field, since the motion of charged particles not only responds to but also creates magnetic fields. The mathematical description of this interaction between the stream of charged particles leaving the Sun and the magnetic field which surrounds the Sun is extremely complicated. The theories which have been used to describe these phenomena are incomplete and often contradictory.

The measurement of interplanetary magnetic fields by Mariner 2 will be combined with simultaneous measurements from Earth to help scientists to understand something about the inter-relationships of these fields.

Moreover, by investigating the magnitude of any Venusian field, it may be possible to draw some conclusions about the interior of the planet, as well as about planetary radiation belts, magnetic storms, and aurorae.

The magnetometer was a three-axis fluxgate type, weighing 4.7 pounds and requiring 6 watts of power. The sensors of the experiment were housed in a metal cylinder 6 inches long and 3 inches in diameter. It was located just below the Mariner's omnidirectional antenna. In this way, the sensors are as far as possible from any spacecraft components that may have magnetic fields associated with them.

Inside the cylinder were three magnetic cores, each aligned along a different axis. Each core has two windings of copper wire around it, much the same as some transformers. The primary winding leads from a frequency oscillator which produces a current. The secondary winding leads to an amplifier.

In the absence of a magnetic field, the current induced in the secondary winding has a special symmetrical wave shape. The presence of a magnetic field changes the symmetry of this wave and produces a component with amplitude in proportion to the field strength. A third winding around the rods prevents magnetic interference from the spacecraft. This feature renders the three axes of the instrument sensitive to 1/2 gamma, or a field strength roughly 100,000 times weaker than that of the Earth.

4. High-Energy Radiation Experiment

This experiment consists of an ionization chamber and a group of three Geiger-Müeller (G-M) tubes. Together, they will measure the number and intensity of energy particles in interplanetary space and near Venus. These particles are primarily cosmic rays, which are made up of protons (the nuclei of hydrogen atoms), alpha particles (the nuclei of helium atoms), the nuclei of heavier atoms, and electrons.

The measurement of these particles may contribute significantly to the knowledge of hazards to manned space flight.

Scientists have theorized that the Sun has a pronounced effect on cosmic rays. During solar activity (Sun spots or flares), for example, huge quantities of plasma race outward from the Sun. These plasma clouds, or solar wind, carry along magnetic fields. In rather complicated manner, not fully understood by scientists, the plasma's magnetic fields interact with those of the Sun and planets. Scientists have noticed that, following this solar activity, there is a considerable change in the character of the radiation that reaches the Earth.

Unfortunately, because of our atmosphere and magnetic field, we cannot measure all of these complicated inter-relationships from Earth. We must take measurements from spacecraft traveling far from the Earth. In this way, we may learn something about the Sun's influence on radiation.

A decrease in the number and intensity of cosmic radiation detected as we go closer to the Sun would indicate that the Sun's magnetic field is deflecting cosmic rays away from the solar system. Thus, by comparing the intensity of magnetic fields with the amount of cosmic radiation at Earth, Venus, and in interplanetary space, some insight may be gained into these complicated inter-relationships.

The ionization chamber was the Neher type. It consists of a 5-inch-diameter stainless steel shell with a wall thickness of 1/100 of an inch. The spere is filled with argon gas and is located on the superstructure of the spacecraft. Inside the sphere, a quartz fibre is placed next to a quartz rod. Initially, both fibre and rod have the same electric potential.

As charged particles penetrate the wall of the sphere, they leave behind a wake of ions in the argon gas. Negative ions accumulate on the rod, giving it a static electric charge. This causes the fibre to be attracted to the rod in proportion to the amount of the charge. Eventually, as the charge increases, the two touch. This produces an electric pulse which was amplified and sent to Earth. The rod is recharged, and the fibre returns to its starting position.

In order to penetrate the wall of the ionization chamber, particles must have an energy greater than 10 million electron volts (Mev) for protons, 1/2 Mev for electrons, and 40 Mev for alpha particles.

The instrument also measures the rate of ionization of cosmic rays. Two of the G-M tubes are considered companion instruments to the ionization chamber. They can be directly penetrated by particles above the same energy levels as the chamber, and can count these particles.

Both tubes consist of an enclosed volume of gas with two electrodes, at a different electrical potential. The walls of the tubes serve as the negative electrode and a thin central wire is the positive electrode. The tubes generate a current pulse each time a charged particle enters.

One of the G-M tubes was shielded by a sleeve of glass and 8/1000 of an inch thickness of stainless steel. The second tube had a beryllium shield 24/1000 of an inch thick. Both tubes are 2.3 inches long and 0.6 inch in diameter. Because of the difference in shields, it will be possible for scientists to infer the ratio of electrons to other particles. These two G-M counters, along with the ionization chamber, make it possible for scientists to measure the flux (velocity times the density) and the average amount of ionization of particles.

A third G-M sensor was the end-window type. It measured the flux of particles not capable of penetrating the other detectors. The window is made of mica and admits protons with energies greater than 1 Mev, and electrons over 40,000 electron volts.

A magnesium shield around the rest of the G-M tube permits passage of protons over 20 Mev and electrons over 1 Mev. This gives the counter the ability to determine the approximate direction of particles which penetrate only the window.

The G-M detectors are mounted on the superstructure of the spacecraft, where they are as far as possible from large masses that tend to produce secondary particles when struck by cosmic rays.

The three G-M tubes protrude from a box that houses their electronic circuitry. The box was 6 inches wide, 6 inches long, and 2 inches thick. The end-window G-M tube was inclined at an angle of 20 degrees from the other two tubes.

The total weight of both experiments was 2.78 pounds and they consume 4/10 of a watt of power.

5. Solar Plasma Detector

The puspose of this detector was to determine the flow and density of solar plasma and the energy of its particles.

Solar plasma is frequently called "solar wind" and consists of charged particles that are continually streaming outward from the Sun. Since direct measurements such as the one on Mariner 2 have been infrequent, scientists know very little about the solar plasma. Some feel that it is merely an extension of the Sun's atmosphere, or corona. Although there are many theories, some conflicting, we do know that during solar activity (Sun spots or flares) the flux of plasma increases.

One of the most complicated and interesting areas of space science is the study of how solar plasma interacts with the magnetic fields in space. Since the plasma carries an electrical charge, it not only is affected by magnetic fields, but also creates one of its own.

If a field is strong enough, it may control and divert the solar winds and, conversely, if the electrical energy in the plasma is great enough, the planetary magnetic fields may be trapped in the cloud and move with it through space. Therefore, to study the complex interactions between solar wind and magnetic fields, space probes that carry plasma experiments generally also carry magnetometers.

Most particle detectors are designed to operate inside a sealed tube and the tube walls keep out very low energy particles. The solar plasma detector on Mariner 2, however, is open to space and can collect and measure positively charged particles of very low energy.

The sensor for this experiment was mounted on the outside of one of the electronic boxes in the base of the spacecraft. The aperture of the analyzer was pointed along the roll axis of the spacecraft and, during most of the mission, will face the Sun.

As charged particle enters the analyzer, it finds itself in a curving tunnel. The two sides of this tunnel are metal plates carrying static electric charges -- one negative, the other positive. The charged particle is attracted by one plate and repelled by the other, and so follows a curved path down the curved tunnel. If it is moving too slowly or too rapidly, it runs into one wall or the other, but if it is moving at just the right speed, it passes to the end and is detected by a charge collecting cup. The electric current produced by the flow of charged particles is measured by a very sensitive electrometer circuit. Thus, all the particles moving in the right direction to enter the tunnel and moving with the right speed to get all the way through will be detected.

Periodically, the amount of voltage on the plates is changed and a different energy is required by the particles to get through to the collector cup. The voltage is automatically changed ten times. In this way, it is possible to measure a spectrum of particle energies of 240 to 8400 electron volts.

The plasma detector had a total weight of 4.8 pounds and a power requirement of 1 watt.

6. Cosmic Dust Detector

This experiment was designed to measure the flux and momentum of cosmic dust in interplanetary space and around Venus. It may contribute to an understanding of the hazards of manned flight through space. This information will also help scientists in understanding the history and evolution of the solar system.

There are many theories about these dust particles. One is that when the solar system was formed billions of years ago by the condensation of a huge cloud of gas and dust, these cosmic particles were debris left over, or they could be remnants of comets that rush through the solar system, leaving a trail of dust behind. Some scientists believe cosmic dust has its origin in galactic space and is somehow trapped by the interaction of magnetic fields from the Sun and planets.

Scientists have been trying to study cosmic dust recently with Earth satellites and sounding rockets, but Mariner 2 provided the first data on its distribution in interplanetary space.

The experiment was located on the top of the spacecraft's hexagonal bus. It consisted of a rectangular magnesium "sounding board" 5 inches wide and 10 inches long. A crystal microphone is located in the center of this plate. This acoustical device measures the impact of particles of cosmic dust.

As a particle hits the acoustical plate, it was recorded by the microphone, whose output excites a voltage-sensitive amplifier. The number of dust particles striking the plate is recorded on two counters, one for particles with high momentum and one for particles with low momentum.

During the cruise phase of the trajectory, the data conditioning system read out the counters every 37 seconds and telemetered this information to the ground. During planetary encounter, the counting rate was reduced to 20-second intervals.

The cosmic dust detector weighed 1.85 pounds and consumed 0.08 milliwatt of power. It was designed by a group of NASA's Goddard Space Flight Center, Greenbelt, Maryland, under the direction of W. M. Alexander.

D. THE VENUS TRAJECTORY

The boost portion of the Mariner mission consisted of three phases: (1) ascent into a circular parking orbit of approximately 115 miles, (2) coast in the parking orbit to a predetermined point in space, and (3) ejection out of the parking orbit to greater-than-escape speed.

The Atlas D-Agena B space booster rises vertically and pitches over in the required direction determined by the exact time of launch. The vehicle gains speed and altitude until a signal from the ground guidance system commands shutdown of the Atlas engines and separation of the Agena-Mariner from the Atlas. The agena engine then ignites after a short coast period and accelerates itself and the spacecraft into the parking orbit at a speed of approximately 18,000 miles per hour.

The Agena-Mariner traveled in a southeasterly direction over the Atlantic Ocean toward the coast of South Africa. Just before reaching Africa, at a point in space determined by the launch date, time of launch, and desired flight time to Venus, the Agena engine will reignite and accelerate the spacecraft to a speed of about 25,503 miles per hour.

Shortly after the Agena engine shut down, the Mariner spacecraft was separated from the Agena. This maneuver is "injection." The speed of the spacecraft exceeds the escape velocity at this altitude by 898 miles per hour and the spacecraft moves off in the hyperbolic orbit relative to Earth. Because of the rapid change of altitude, the rate at which it moves around the Earth decreases until it is traveling essentially in a straight line outward from Earth. During the time from injection to escape, the radius vector from the Earth's center to the spacecraft moves through an angle of approximately 148 degrees.

At the same time that it was moving out, the spacecraft was slowing down relative to Earth because of Earth's gravity. When it reached a distance of about 600,000 miles, after about 3 days, and had essentially "escaped Earth," the velocity decreased from the original 25,503 to 6874 miles per hour. The time and direction of the second Agena burn was chosen so that this velocity relative to Earth is in a direction opposite to that of the Earth in its orbit about the Sun. Thus, the spacecraft was moving about the Sun 6874 miles per hour slower than the Earth's approximate 66,000 miles per hour; that is, about 59,426 miles per hour.

Because of the lower orbital velocity about the Sun, the spacecraft was moving too slowly to maintain a circular orbit against the Sun's gravity. It, therefore, started falling inward toward the orbit of Venus. The combination of the inward motion and the circular motion around the Sun produced an ecliptic orbit (Fig. 9) that will intersect the orbit of Venus some 109 days later in the case of Mariner 2.

About 8 days after launch, the accumulated tracking data was used to compare the trajectories of the spacecraft with the trajectory necessary to provide the planned Venus encounter. The midcourse maneuver depended on the difference between these two trajectories.

Now, Mariner began to curve in toward the Sun and gradually increased its speed. Eventually, due to the inward curving path, Mariner's speed exceeded that of the Earth and it passed Earth. Later, it overtook the rapidly moving Venus, approaching the planet on its dark side at a speed of more than 84,000 miles per hour relative to the Sun.

Entering the sphere of gravitational influence of the planet, Mariner's path was deflected because of its pull. Its speed was increased even more, reaching over 91,600 miles per hour relative to the Sun as it passed Venus on its sunny side at a distance of 21,648 miles from the surface. In addition, Mariner's path was bent about 40 degrees in traveling past the planet.

About 65 minutes before closest approach, or at a distance of 18,600 miles from the planet's surface, the planetary experiments on Mariner began to scan Venus.

The path of the spacecraft in the vicinity of Venus was designed so that Venus would not block the spacecraft's view of either the Sun or Earth. This was necessary to ensure continuous communication with Earth and proper functioning of the Sun and Earth sensors. The latter provide reference directions for attitude control of the spacecraft. The communication distance at the time of arrival was about 36,000,000 miles.

After leaving the sphere of influence of Venus, the spacecraft had even greater speed than when it entered. In essence, it experienced an increase in energy and speed due to the bending of its course by Venus. This phenomenon is similar to that sometimes experienced by comets which travel too close to the planet Jupiter. The energy increase is sometimes

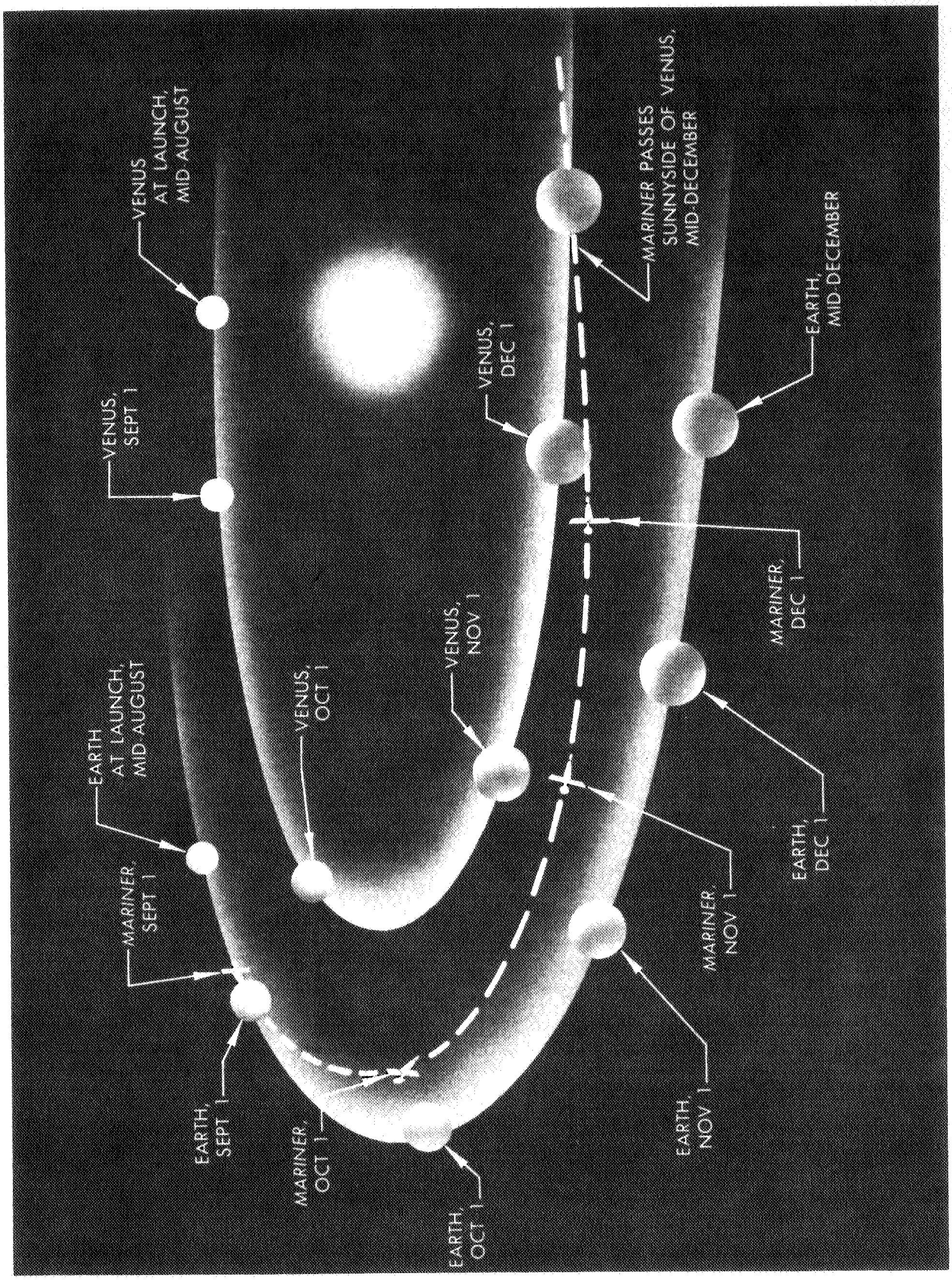


Figure 9. Typical Mariner 2 trajectory to the vicinity of Venus

sufficient to cause the comet to escape the solar system. Such was not the case for Mariner, however.

Designing an interplanetary trajectory is a complex task that taxes the capabilities of high-speed computers. The trajectory engineer faces a task complicated by the interactions of the motion of the Earth about the Sun, the motion of Venus, the spin of the Earth, and the effect of gravitational fields of Earth, Sun, Moon, Venus, Jupiter, and even the pressure of the Sun's radiation, on the path of the spacecraft.

The trajectory designer, therefore, must calculate a trajectory from minute to minute for that portion of each day during the launch opportunity that launch could occur. He must keep his trajectory within range safety limits (the early portions of the launch must be over water, not land masses) and he must keep the trajectory within range of the tracking stations.

Meshing all these factors into a successful trajectory spanning millions of miles and nearly 4 months in time was a formidable task.

E. DEEP SPACE INSTRUMENTATION FACILITY

Two-way communication with Mariner was provided by JPL's Deep Space Instrumentation Facility (DSIF), a world circling network of three permanent tracking stations, a mobile tracking unit, and (at the Atlantic Missile Range, Cape Canaveral, Florida) a launch checkout station.

The DSIF is under the technical direction of the Jet Propulsion Laboratory for the National Aeronautics and Space Administration. Dr. Eberhardt Rechtin is JPL's DSIF Program Director.

The DSIF tracked Mariner 2 throughout the 130-day mission, received and recorded telemetry from the spacecraft, and transmitted commands to it.

The three permanent stations are at Goldstone in California's Mohave Desert, near Woomera Village in Australia, and near Johannesburg, South Africa. These installations are located approximately 120 degrees apart around the Earth. Their ranges overlap to provide continuous contact with the spacecraft.

The mobile station was located approximately 1 mile east of the DSIF installation at Johannesburg. This station acquired Mariner shortly after injection, when the spacecraft was too low to be readily tracked by the larger antenna. The mobile station is equipped with a 10-foot-diameter dish antenna with a wide (9 degree) beam width and a fast tracking capability of 10 degrees per second.

The larger 85-foot-diameter antenna of the permanent installation has a 1-degree beam width and a one-degree-per-second tracking capability.

As soon as the mobile station had acquired Mariner, tracking information and the position of the spacecraft was sent to the permanent installation, telling it where to look. The large antenna locked onto Mariner shortly thereafter.

The installations at Johannesburg and Goldstone had the capability of sending commands to Mariner, in addition to receiving telemetry. The Woomera installation, the mobile unit, and the launch checkout station could not command, but could transmit a signal to the spacecraft for doppler calculations. The mobile and launch checkout stations do not have the range of the larger antennas and function only in the initial stages of the mission.

The following are typical visibility times based on one possible launch date and time. The figures would change slightly relative to the actual date and hour that launch occurred. Since the mobile and South African stations are close together, they have the same visibility periods. The times when the spacecraft will be visible to the different stations are shown. I = injection, which occurs at the end of the Agena second burn.

Station	Visibility periods	
Johannesburg and mobile	I + 2 minutes	I + 26 minutes
Woomera	I + 17 minutes	I + 6 hours 35 minutes
Johannesburg and mobile	I + 1 hour 45 minutes	I + 14 hours 10 minutes
Goldstone	I + 13 hours	I + 23 hours 10 minutes
Woomera	I + 19 hours 15 minutes	I + 31 hours 10 minutes
Johannesburg	I + 26 hours 40 minutes	I + 38 hours 25 minutes

Throughout the mission, the stations continued to lock onto the spacecraft, track it until the rotation of the Earth carried the station to the limits of its horizon, and then pass the spacecraft on to the next station.

During the entire Venus mission, the DSIF stations essentially maintained contact with Mariner 24 hours per day.

Each station was manned by a 25-man staff. It takes 3 hours to prepare a station to acquire the spacecraft and 1 hour to shut down following a tracking period.

Each station was linked with the Space Flight Operations Center at JPL by leased teletype circuits over which was sent all tracking and telemetry information for processing by an IBM 7090 computer system.

The launch checkout station at Cape Canaveral received telemetry from the spacecraft during prelaunch tests and recorded spacecraft telemetry from launch until the station lost contact with Mariner as it passed over the horizon. The station has two trailers: one for the transmitter and receiver and the other for test equipment, recording equipment, and equipment for processing portions of the received signal for real-time display on strip charts; a 6-foot-diameter dish antenna for receiving and transmitting; and a collimation tower for calibrating and checking station equipment. The tower simulates the spacecraft for checkout procedures, transmitting on the same frequencies used by Mariner. The station had a 15-man crew.

The Goldstone station is operated for JPL by the Bendix Radio Corporation. JPL's engineer in charge was Walter Larkin. Goldstone has two 85-foot-diameter antennas separated by 7 miles and a ridge of hills to minimize interference.

The Australian station is 15 miles from Woomera Village and has one 85-foot-diameter receiving antenna. The station is operated by the Australian Department of Supply, Weapons Research Establishment. Dr. Frank Wood represents the WRE. Richard Fahnestock was the resident engineer for JPL.

The South African station is equipped with an 85-foot-diameter receiving antenna and is located in a bowl-shaped valley approximately 40 miles northwest of Johannesburg. The station is operated by the South African government through the National Institute for Telecommunications Research, Dr. Frank Hewitt, Director. NITR is a division of the Council for Scientific and Industrial Research. Resident engineer for JPL was Paul Jones.

SECTION II

MARINER 2 FLIGHT LOG

Mariner 2 was successfully launched by an Atlas D/Agena B vehicle on August 27, 1962 at 1:53 a.m., EST, from the Atlantic Missile Range, Cape Canaveral, Florida.

5:00 a.m., August 27, 1962 Mariner 2, 0 Day

Early tracking data from Mariner 2 indicated that the spacecraft will pass within 600,000 miles of Venus in the second week of December. It will be possible to refine this number to a greater accuracy as more data is received. The midcourse motor on the spacecraft has the capability to correct the miss distance to bring the spacecraft within the desired target zone of 8,000 to 4,000 miles of Venus.

All systems of Mariner are working normally and good telemetry is being received by the Deep Space Instrumentation Facility stations.

12:30 p.m., August 27, 1962

Calculations based on additional tracking data from Mariner 2 show that the spacecraft is on a trajectory which will take it to a point in space 233,000 miles from Venus. This is a result of normal dispersions in the Atlas Agena launch vehicle.

Arrival time at the planet Venus will be pin-pointed after completion of the midcourse maneuver. The midcourse maneuver is expected to take place eight days after the launch. In performing the maneuver the Mariner has to change its attitude in space in response to a command from the ground and fire its midcourse motor to add a velocity of about 80 miles an hour to the spacecraft speed. The midcourse motor has a capability of adding 120 miles an hour to the spacecraft velocity.

All systems on the spacecraft are working normally and the telemetry quality is described as excellent.

The distance of Mariner from Earth at noon, PDT, was 113,294 miles.

Noon, August 28, 1962 Mariner 2, 1st Day

Mariner 2 was 296,836 miles from the Earth traveling at a velocity of 7,312 miles per hour (relative to Earth) on its curving 180.2 million mile journey to fly by Venus. Scientists at the Caltech Jet Propulsion Laboratory now are making calculations as to when to send the 448-pound spacecraft the command that will change its course to fly by Venus at the desired miss distance.

2:00 p.m., August 29, 1962 Mariner 2, 2nd Day

At 9:13 a.m. PDT, when the spacecraft was 447,897 miles from the Earth and traveling at a velocity of 7,117 miles per hour, a command was sent to it from the Johannesburg station to switch on the four interplanetary scientific experiments. The command was executed and the four scientific experiments immediately responded by sending data. It will take some time, however, to evaluate the quality of the data, but at the moment it is possible to say that all four experiments are in working condition.

The four experiments, designed to provide information about the interplanetary environment in which man will later travel, are:

(1) A magnetometer to measure changes in the interplanetary magnetic fields.

(2) An ion chamber and particle flux detector to measure charged particle intensity and distribution in interplanetary space.

(3) A cosmic dust detector to measure the density and distribution of cosmic dust.

(4) A solar plasma spectrometer to measure the intensity and velocities of low energy protons from the Sun.

Until the time the science was turned on, the spacecraft had been sending only engineering telemetry, such as temperature measurements, roll rate, pressure measurements and measurements of solar power available to run the spacecraft.

Noon, August 30, 1962 Mariner 2, 3rd Day

The midcourse maneuver attempt probably will be made Monday, September 3 to alter the flight path of the spacecraft so it will fly by the planet Venus at a distance of about 10,000 miles.

The midcourse correction commands will be sent from the Deep Space Instrumentation Facility at Goldstone, California. Goldstone is scheduled to acquire the spacecraft at 12:04 p.m., PDT, Monday and remain locked on to it until 10:58 p.m., PDT, Monday. The midcourse correction will be made during this period. At the time of the correction, Mariner will be about 1.5 million miles from Earth. Before the correction, the spacecraft will be traveling away from the Earth at a velocity of about 6,780 mph. The direction of the midcourse maneuver will be such as to decrease the velocity slightly.

An important step prior to midcourse correction is Earth acquisition. This is scheduled to take place some time Sunday.

During Earth acquisition, the spacecraft maintains its lock on the Sun but positions itself so the high gain antenna is pointing towards the Earth. This is necessary to position properly the spacecraft for the midcourse correction.

1:00 a.m. PDT, September 3, 1962 Mariner 2, 7th Day

At 10:30 p.m. PDT, Sunday, September 2, when Mariner 2 was approximately 1.2 million miles from the Earth and traveling at a velocity of 6,806 miles per hour, it successfully acted upon a stored command in the spacecraft and started a process called Earth acquisition. In this process, the spacecraft continued to hold its attitude in which it points its solar panels at the Sun but rolled on its long axis, turned on its Earth sensors and stabilized its attitude so that the high gain directional antenna pointed at the Earth.

All functions and subsystems appeared to be operating in a normal manner except that the indicated Earth sensor sensitivity was low, reading a value which would be approximately correct in case of an acquisition of the Moon rather than the Earth.

2:45 p.m. PDT, September 3, 1962

The Mariner 2 midcourse maneuver did not take place today. It was decided to wait 24 hours in order to establish more firmly whether the Earth sensor is locked on the Earth or the Moon. Neither of these situations is detrimental to the long range success of the mission, because as the spacecraft gets farther out on its 180.2 million mile journey to Venus, the Earth and Moon blend into one image. However, in order to execute the midcourse maneuver with greater assurance of success, it is necessary to know at this relatively short range whether the sensor is looking at the Moon or the Earth.

5:40 p.m. PDT, September 4, 1962 Mariner 2, 8th Day

It was determined that the Earth sensor was locked on the Earth and at 3:49 p.m., PDT, Mariner 2 was sent the midcourse maneuver commands designed to change its course in space and send it by the planet Venus at a miss distance of about 10,000 miles. At 4:49 p.m., PDT, the spacecraft executed the command.

Preliminary data indicate that the pitch and roll changes were made to point the spacecraft in the proper direction and the midcourse motor did ignite and burn for the required time. The midcourse motor was ignited at 5:24:35 p.m., PDT, when the spacecraft was 1,492,500 miles from Earth.

The Earth sensor sensitivity is still indicating a low value, the cause of the condition is unknown at this time.

September 8, 1962 Mariner 2, 12th Day

At approximately 5:50 a.m., PDT, the science instruments were automatically turned off for about 3 minutes. This was possibly caused by a momentary loss of lock on the Earth or the Sun. The gyros were turned on (a normal operation in this condition) but all sensors were back in lock within a few seconds, before any telemetry samples could indicate which axis had lost lock. The science instruments were automatically turned back on at the end of the minimum gyro on cycle of about 3 minutes. This loss of lock could conceivably have been a result of a micrometeorite hit in the spacecraft.

September 23, 1962 — Mariner 2, 27th Day

At 1 a.m., PDT, Monday, September 24, the Mariner 2 will be 4,510,268 miles from the Earth and thus will have surpassed the record of the Soviet Union's Venus spacecraft which stopped transmitting when it was 4.5 million miles from the Earth eighteen days after it was launched. Mariner 2 is transmitting telemetry on all channels and it is reporting on the interplanetary environment through which it is traveling.

September 29, 1962 — Mariner 2, 33rd Day

At approximately 7:34 a.m., PDT, the science instruments were automatically turned off for about 3 minutes and the spacecraft gyros came on. When all subsystems were back to the normal operating mode, the Earth sensor sensitivity indication was up to a value equal to the prelaunch predicted value for this day.

October 30, 1962 — Mariner 2, 64th Day

The Mariner 2 spacecraft today marked its 64th day of space travel by passing the Earth in its 109 day flight to the planet Venus. This occurred at 5:00 a.m., PST, when the 448-pound spacecraft was 11.5 million miles from Earth--about half the distance to the orbit of Venus--and traveling at a speed of 70,500 miles per hour in relation to the Sun.

3:00 p.m., November 8, 1962 — Mariner 2, 73rd Day

The four interplanetary scientific experiments on Mariner 2 were turned on again today by command from the Goldstone tracking station when the spacecraft was more than 14.6 million miles from the Earth. This means that the spacecraft is back in its normal cruise condition. The four experiments--a magnetometer, an ion chamber and particle flux detector, a cosmic dust detector and a solar plasma detector--were turned off October 31 in order to reduce the power demand on the spacecraft when a drop in power supplied by the solar panels was noted.

After a little more than a week during which the spacecraft sent back only engineering information and operated properly on the power available, the telemetry indicated that the power supply from the solar panels had increased to its normal level.

November 15, 1962 — Mariner 2, 80th Day

Mariner 2 established a new deep space measurement communications record today as it transmitted engineering and scientific data to Earth from nearly 18 million miles in space.

The earlier communications record was set by this country's Pioneer V space probe at a distance of 17.7 million miles. At that distance, on June 14, 1960, Pioneer V's signal strength dropped below the minimum for transmission of data.

At 4:22 p.m., PST, the drop in power supplied by the solar panels reappeared. The power available is sufficient to allow leaving the science instruments turned on. Power available from the solar panels is related to the spacecraft to Sun distance; as the distance decreases, the available power goes up.

November 25, 1962 — Mariner 2, 90th Day

Mariner 2 has passed the communications record distance. At 4:46 a.m., PST, Mariner was communicating with Earth at 22.5 million miles, further than any spaceprobe has ever communicated back to Earth.

December 9, 1962 — Mariner 2, 104th Day

At 3:20 p.m., PST, four telemetry measurements were lost. These were the high gain antenna hinge angle, attitude control gas pressure, midcourse propulsion gas pressure and midcourse propulsion fuel tank pressure.

5:35 a.m., December 14, 1962 — Mariner 2, 109th Day

At 5:35 a.m., PST, the Goldstone Tracking Station in the California desert flashed a radio command to Mariner 2 across 36 million miles of space as the spacecraft neared Venus.

Six and a half minutes later, Goldstone received verification that the spacecraft had received and acted on the command and the two radiometers onboard started to scan. The spacecraft also went into the Venus encounter mode, in which it shifts from sending mixed science and engineering telemetry into a mode in which it sends all science telemetry.

Prior to the Goldstone action, the Central Computer and Sequencer--the central clock and timer aboard the spacecraft--twice had tried to turn the radiometers on and put the spacecraft into an encounter mode, and twice had failed. The decision then was made to send the command from Goldstone. This action represents a communication record in successfully transmitting a command over 36 million miles in space.

Mariner is expected to pass by Venus at a distance of approximately 21,000 miles at about noon today climaxing a journey of 180.2 million miles over 109.5 days. During the fly-by four experiments which have been on almost continuously since launch will report on conditions in the vicinity of Venus. These are: magnetic fields, cosmic dust, charged particles and solar plasma.

The two radiometers--infrared and microwave--are designed to scan the planet and report on the cloud cover and surface temperatures. The scan will start at 10:55 a.m. and terminate at 11:37 a.m., PST.

At the time that the radiometers' scan mechnaism is turned on, Mariner will be approaching the planet from the dark side and moving in a downward direction. As seen from Venus, the spacecraft will be moving in a direction to the right and below the Sun.

As Mariner cruises past Venus its solar panels will remain locked on the Sun to obtain electrical power. The radiometers point in a direction perpendicular to the roll axis of the spacecraft and move in a nodding motion across the surface of Venus at a rate of one-tenth of a degree per minute. As Mariner passes Venus, the radiometers will first scan the dark side and then the sunlit side.

This planetary scanning period will last for 42 minutes. During this time, the findings of all six scientific experiments will be transmitted to the Woomera and Goldstone DSIF stations.

At 66 minutes before the point of closest approach, or 10:55 a.m., December 14, Mariner will be 25,262 miles from Venus. At that time its velocity will have increased to approximately 87,000 mph due to the gravitational pull of the planet. At this time the radiometers should detect the planet's surface for the first time.

At 44 minutes before the point of closest approach, or 11:17 a.m., Mariner will pass the planet's terminator, or dividing line between light and darkness. It will still be moving downward and picking up speed.

Drawn by the gravitational field of Venus the spacecraft continues to accelerate. By 11:37 a.m. the scanning period ends as Venus moves out of sight of the radiometers. At that point in time, Mariner will be going approximately 87,000 mph. Venus will be approximately 21,700 miles away while the Earth is about 36,000,000 miles away.

Twenty-three minutes later, at 12:01 p.m., Mariner will reach the position of closest approach, approximately 21,000 miles from Venus. It will be traveling approximately 88,400 mph.

The gravitational attraction of Venus will have increased Mariner's velocity by 1,400 mph in one hour. As the spacecraft starts moving away from Venus, gravity reverses its effect and starts slowing the spacecraft down. In addition to changing the speed of the spacecraft, the gravitational field also will bend Mariner's trajectory by about 25 degrees during encounter.

After closest approach, Mariner will be sent a radio command to turn off its radiometers and return to the cruise mode. When the command is obeyed the spacecraft will resume the sending of engineering data and will continue to take measurements with its interplanetary instruments.

On December 27, it will reach its closest point to the Sun, 65,539,000 miles. At this time, its velocity will be approximately 85,300 mph. It will be 2,700,000 miles from Venus and Mariner then will be 44,213,000 miles from Earth in a heliocentric orbit around the Sun.

Uncertainties in Mariner's trajectory resulted from: the effect of solar pressure, the mass and gravitational fields of the Earth and Venus, the exact location of ground tracking stations and the astronomical unit.

Refinements in these uncertainties will be achieved by analysis of the tracking and doppler data collected during Mariner's trip and during the encounter phase when Mariner's trajectory is perturbed by Venus gravity.

The doppler effect is a principle of physics in which the frequency of radio waves appear to increase when a transmitter and receiver are approaching each other, and to decrease when they are moving apart. The speed of Mariner is determined by analysis of the frequency of its signals.

December 27, 1962 Mariner 2, 122nd Day

At 9:10 p.m., PST, the spacecraft reached its point of closest approach to the Sun. The spacecraft to Sun distance at this point was 65,793,000 miles.

December 30, 1962 Mariner 2, 125th Day

At 11:28 a.m., PST, the spacecraft reference frequency source failed and the frequency changed to its natural resonant frequency. This resulted in lowering the telemetry bit from 8.33 bits per second to 7.59 bits per second.

January 3, 1963 Mariner 2, 129th Day

Mariner 2, lost its contact with Earth after 129 days of flight, when it was 54.3 million miles from the Earth and 5.7 million miles from Venus.

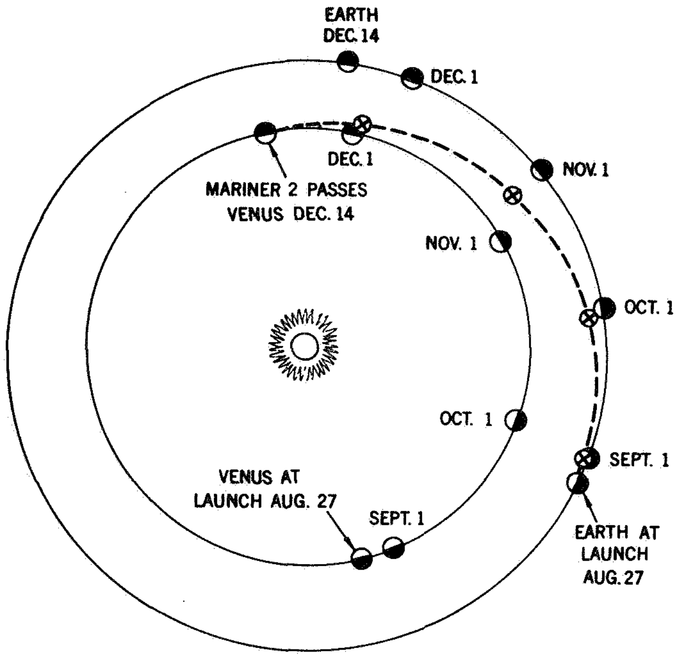
Mariner set a communications record, sending useful telemetry information continuously over a distance of more than 54 million miles.

January 10, 1963

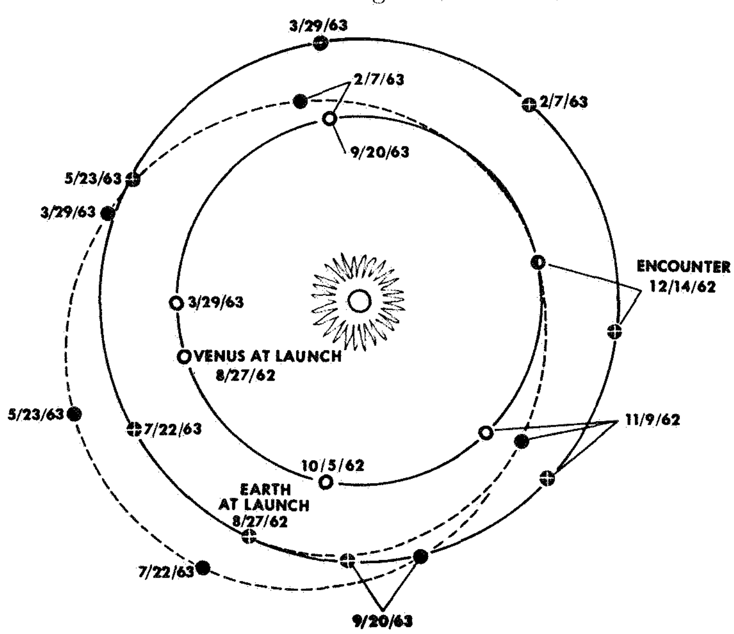
The complete success of the Mariner 2 has made it possible for the National Aeronautics and Space Administration to modify its program of planetary exploration.

NASA announced that instead of repeating the Venus mission in 1964, it will concentrate on other projects such as the Mars mission now also planned for 1964, and later Venus missions with advanced Mariner spacecraft.

Because of the long lead times necessary to prepare for planetary missions, plans for the 1964 flights had to be initiated well before completion of the Mariner 2 flight. In the light of the mass of data obtained by Mariner 2, NASA, on the recommendation of the Jet Propulsion Laboratory, has eliminated a repetition of the Venus mission which until now had been planned for the time of the next Venus opportunity in 1964.

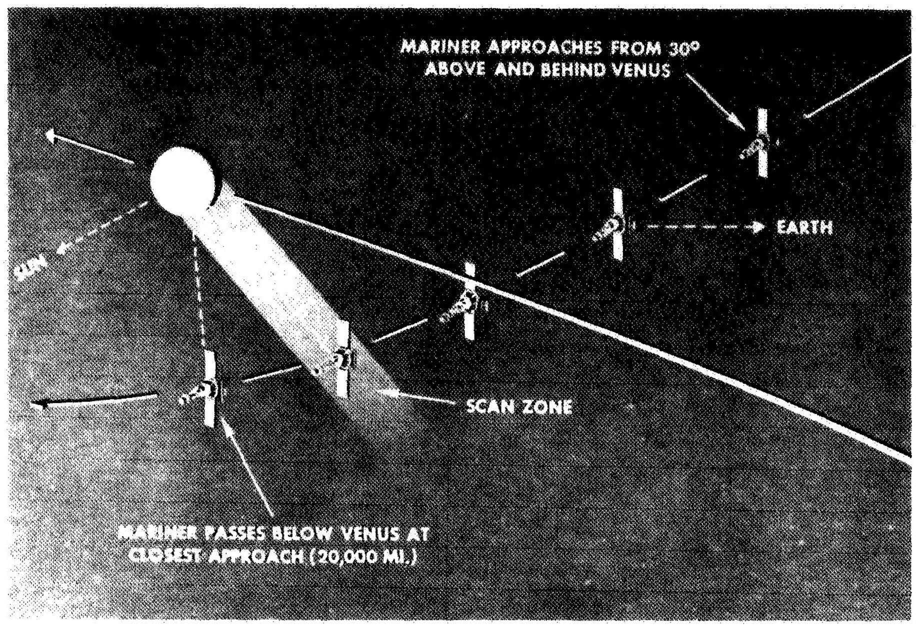


Mariner 2 Flight Path to Venus

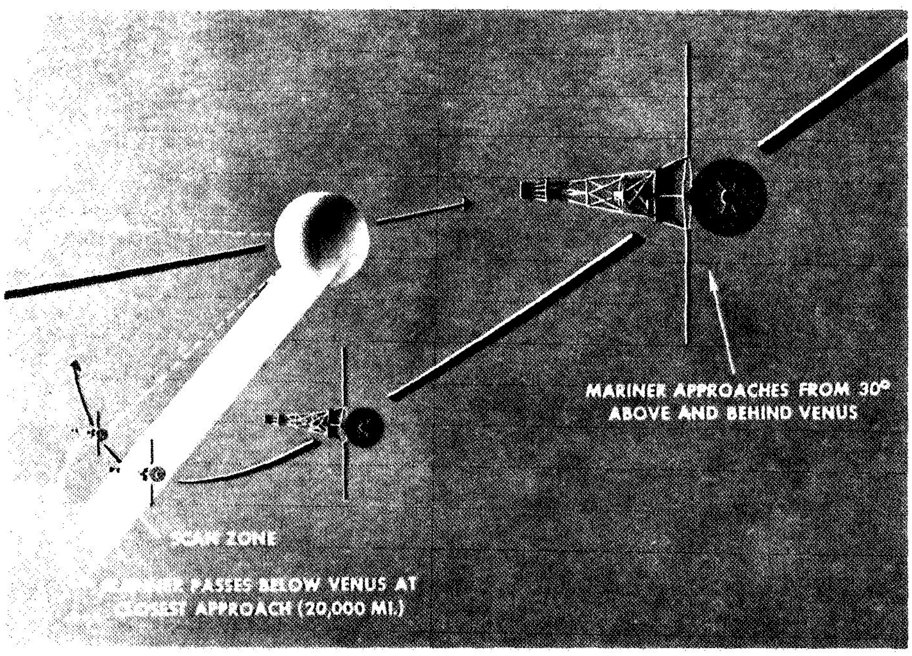


Solar Orbit of Mariner 2

Diagram released by the Jet Propulsion Laboratory of the California Institute of Technology depicts the path that the Mariner spacecraft will follow after the fly-by of Venus on December 14. Mariner will become a satellity of the Sun and follow an orbital path that will carry it outside the orbit of Earth and back to the orbit of Venus.



Mariner 2 Pass of Venus as Seen from Inside Venus Orbit



Mariner 2 Pass of Venus as Seen from Earth

Path of the Mariner spacecraft during the December 14 fly-by of the planet Venus depicted in by artist's concept released by the Jet Propulsion Laboratory of the California Institute of Technology. Scan zone of drawing delinated period of time that two planetary experiments, infrared and microwave radiometers will be able to measure infrared and microwave radiation from Venus.

SECTION III

TABLE OF DISTANCE AND VELOCITY DURING FLIGHT

Date P.D.T.	Day	Distance from Earth - Miles	MPH Relative to Earth	MPH Relative to Sun	Distance from Venus
8/27/63	0				
12:19 AM		4081	25550		
4:00 AM		45025	10012		
8:00 AM		81309	8698		
12:00 Noon		114654	8173		
4:00 PM		146548	7879		
8:00 PM		177552	7689		
12:00 MN		207947	7554		
8/28/62	1				
4:00 AM		237895	7454		
8:00 AM		267501	7375		
12:00 Noon		296834	7312		
Time of measurement for following days - 12:00 Noon					
8/29/62	2	469187	7093		
8/30/62	3	637957	6986		
8/31/62	4	804709	6917		
9/1/62	5	970069	6867		
9/2/62	6	1134339	6825		
9/3/62	7	1297682	6788		
9/4/62	8	1460192	6755		
Time of measurement for following days - 11:00 AM					
9/5/62	9	1614000	6661	60233	
9/6/62	10	1773000	6631	60322	
9/7/62	11	1932000	6603	60413	

Date P.D.T.	Day	Distance from Earth- Miles	MPH Relative to Earth	MPH Relative to Sun	Distance from Venus
Time of measurement for following days - 1:00 PM					
9/8/62	12	2103985.9	6577.9	60510.7	57515267
9/9/62	13	2261543.1	6552.6	60608.7	56637690
9/10	14	2418511.6	6529.5	60709.9	55760870
9/11	15	2574942.1	6508.9	60814.5	54885019
9/12	16	2730894.1	6491.1	60922.5	54010352
9/13	17	2886434.3	6476.5	61034.2	53137098
9/14	18	3041633.4	6465.1	61149.4	52265470
9/15	19	3196561.6	6456.9	61268.4	51395693
9/16	20	3351284.5	6451.6	61391.1	50527991
9/17	21	3505861.1	6448.8	61517.6	49662582
9/18	22	3660342.7	6448.5	61647.9	48799694
9/19	23	3814774.9	6450.2	61781.9	47939546
9/20	24	3969200.2	6454.2	61919.8	47082364
9/21	25	4123660.5	6460.4	62061.6	46228370
9/22	26	4278200.6	6469.1	62207.2	45377783
9/23	27	4432869.2	6480.5	62356.0	44530828
9/24	28	4587721.0	6495.1	62510.1	43687725
Time of measurement for following days - 11:00 AM					
9/25	29	4725095.0	6507	62658.0	42923168
9/26	30	4880376.0	6529	62819.0	42088202
9/27	31	5036051.0	6555	62984.0	41257723
9/28	32	5192212.0	6586	63152.0	40431949
9/29	33	5348963.0	6623	63324.0	39611096
9/30	34	5506421.0	6667	63501.0	38795372

Date P.D.T.	Day	Distance from Earth - Miles	MPH Relative to Earth	MPH Relative to Sun	Distance from Venus
10/1	35	5664717.0	6717	63681.0	37984993
10/2	36	5823996.0	6774	63864.0	37180166
10/3	37	5984417.0	6840	64052.0	36381098
10/4	38	6146156.0	6915	64244.0	35587991
10/5	39	6309404.0	6992	64439.0	34801054
10/6	40	6474368.0	7032	64639.0	34020483
10/7	41	6641269.0	7196	64842.0	33246476
10/8	42	6810349.0	7311	65049.0	32479226
10/9	43	6981860.0	7438	65260.0	31718928
10/10	44	7156070.0	7575	65474.0	30965766
10/11	45	7333258.0	7724	65693.0	30219929
10/12	46	7513706.0	7885	65915.0	29481593
10/13	47	7697698.0	8056	66141.0	28750936
10/14	48	7885510.0	8237	66370.0	28028130
10/15	49	8077415.0	8428	66604.0	27313345
10/16	50	8273671.0	8628	66840.0	26606741
10/17	51	8474534.0	8837	67081.0	25908478
10/18	52	8680254.0	9055	67325.0	25218708
10/19	53	8891076.0	9282	67573.0	24537579
10/20	54	9107250.0	9517	67825.0	23865230
10/21	55	9329027.0	9761	68080.0	23201796
10/22	56	9556660.0	10014	68338.0	22547402
10/23	57	9790408.0	10276	68600.0	21902176
10/24	58	10030530.0	10547	68865.0	21266225
10/25	59	10277292.0	10828	69134.0	20639655
10/26	60	10530959.0	11118	69406.0	20022562
10/27	61	10791803.0	11418	69861.0	19415038

Date P.S.T.	Day	Distance from Earth - Miles	MPH Relative to Earth	MPH Relative to Sun	Distance from Venus
10/28	62	11060096.0	11728	69959.0	18817157
10/29	63	11336115.0	12049	70241.0	18228991
10/30	64	11620139.0	12379	70526.0	17650598
10/31	65	11912448.0	12720	70813.0	17082025
11/1	66	12213324.0	13072	71104.0	16523309
11/2	67	12523050.0	13435	71397.0	15974477
11/3	68	12841909.0	13808	71694.0	15435541
11/4	69	13170184.0	14193	71993.0	14906500
11/5	70	13508152.0	14589	72294.0	14387342
11/6	71	13856089.0	14996	72598.0	13878040
11/7	72	14214262.0	15414	72905.0	13378552
11/8	73	14582928.0	15843	73214.0	12888822
11/9	74	14962328.0	16283	73525.0	12408781
11/10	75	15352686.0	16732	73838.0	11938340
11/11	76	15754207.0	17192	74153.0	11477399
11/12	77	16167067.0	17660	74470.0	11025831
11/13	78	16591425.0	18137	74788.0	10583519
11/14	79	17027418.0	18622	75108.0	10150293
11/15	80	17475166.0	19116	75430.0	9725990
11/16	81	17934779.0	19618	75753.0	9310423
11/17	82	18406353.0	20128	76077.0	8903389
11/18	83	18889980.0	20646	76402.0	8504668
11/19	84	19385742.0	21173	76727.0	8114025
11/20	85	19893715.0	21708	77053.0	7731206
11/21	86	20413968.0	22252	77389.0	7355942
11/22	87	20946562.0	22804	77766.0	6987954
11/23	88	21491553.0	23365	78032.0	6626942
11/24	89	22048985.0	23835	78358.0	6272595

Date P.S.T.	Day	Distance from Earth - Miles	MPH Relative to Earth	MPH Relative to Sun	Distance from Venus
11/25	90	22618901.0	24514	78683.0	5924592
11/26	91	23201332.0	25101	79008.0	5582598
11/27	92	23796305.0	25698	79331.0	5246270
11/28	93	24403841.0	26304	79653.0	4915256
11/29	94	25023951.0	26919	79974.0	4589199
11/30	95	25656642.0	27543	80293.0	4267737
12/1	96	26301910.0	28177	80610.0	3950501
12/2	97	26959744.0	28820	80924.0	3637124
12/3	98	27630123.0	29473	81235.0	3327239
12/4	99	28313011.0	30135	81544.0	3020477
12/5	100	29008361.0	30806	81850.0	2716478
12/6	101	29716110.0	31486	82152.0	2414880
12/7	102	30436178.0	32176	82450.0	2115331
12/8	103	31168474.0	32875	82745.0	1817477
12/9	104	31912889.0	33583	83036.0	1520969
12/10	105	32669316.0	34301	83325.0	1225447
12/11	106	33437672.0	35032	83612.0	930253
12/12	107	34217983.0	35787	83905.0	635222
12/13	108	35010741.0	36610	84234.0	340303
12/14(PST)	109				
11:00 AM		35869499.0	39959.9	87152.9	24673.5
11:15.9 AM		35879232.0	40163.1	87481.6	23113.3
11:36.9 AM		35892235.0	40399.5	87938.6	21690.4
12:00 Noon		35906694.0	40572.4	88415.9	21118.3
1:00 PM		35944642.0	40480.0	89141.9	24600.6
12/15(PST)	110				
12:00 Noon		36794927.0	38962.3	88498.1	303400.4
4:00 PM		36941662.0	39028.4	88491.3	352781.6

Date P.S.T.	Day	Distance from Earth - Miles	MPH Relative to Earth	MPH Relative to Sun	Distance from Venus
Time of measurement for following days 4:00 PM					
12/16 (PST)	111	37827135.0	39546.5	88589.4	648414.1
12/17 (PST)	112	38719004.0	40121.8	88721.7	942918.7
12/18 (PST)	113	39617537.0	40710.5	88853.8	1236820.1
12/19 (PST)	114	40522476.0	41302.0	88977.4	1530258.8
12/20 (PST)	115	41433411.0	41892.1	89089.2	1823227.8
12/21 (PST)	116	42349857.0	42478.6	89187.6	2115636.2
12/22 (PST)	117	43271304.0	43060.3	89271.8	2407347.0
12/23 (PST)	118	44197208.0	43635.9	89341.2	2698177.4
12/24 (PST)	119	45127023.0	44204.9	89395.3	2987920.6
12/25 (PST)	120	46060183.0	44766.4	89433.9	3276335.9
12/26 (PST)	121	46996133.0	45320.0	89456.7	3563170.2
12/27 (PST)	122	47934307.0	45865.2	89463.8	3848147.4
12/28 (PST)	123	48874142.0	46401.6	89454.9	4130979.7
12/29 (PST)	124	49815075.0	46928.9	89430.1	4411366.1
Time of measurement for following days - 12:00 Noon					
12/30	125	50756552	47446.8	89389.4	4689005.1
12/31	126	51698020	47955.0	89332.9	4963585.6
1/2/63	127	53400000	48946	89185.0	5470000
1/3/63	128	54300000	49430	89087.0	5730000

SECTION IV

RESULTS OF THE MARINER 2 MISSION

A. INTRODUCTION

Venus is covered by cold dense clouds in the upper atmosphere; it has surface temperatures on the order of 800 degrees Fahrenheit; it has a cold spot in the southern hemisphere; the temperatures are essentially the same on both the dark and sunlighted sides; it is without the high density electron ionosphere that some scientists had speculated existed there; and the amount of carbon dioxide in the atmosphere above the cloud layer is too small to be detected by the Mariner instruments.

The radiometers made three complete scans of the planet, one on the sunlighted side, one on the dark side and one across the terminator. (The terminator is the line separating the sunlighted side from the dark side.) A total of eighteen data points were obtained--five readings from the sunlighted side, five from dark side and eight across the terminator.

From these readings, it is possible to determine the temperatures of the cloud cover and of the surface, or relatively close to the surface.

The results tend to confirm some theories that had existed concerning the nature of Venus and overthrow other theories.

Although Venus is our closest planetary neighbor, Earth based observations are hampered by the combination of the atmospheres of the two planets and the distance separating them. At inferior conjunction, Venus is some 26 million miles from the Earth. At the time of the Mariner fly-by, Venus was 36 million miles from the Earth.

Earth based spectrographic observations (identification of materials according to the manner in which they emit or absorb light) have indicated that the atmosphere of Venus contains carbon dioxide, but probably has little free oxygen or water vapor.

Other Earth based measurements have been made in the microwave and infrared regions of the spectrum to try to detect surface temperatures. The terrestrial microwave measurements showed brightness temperatures of approximately 600 degrees Fahrenheit near the surface, averaged over the entire planet, and the infrared measurements showed readings of minus 40 degrees Fahrenheit in the upper atmosphere. But because of the distances over which the measurements were made and other factors, the scientists who took them could not be sure of the significance of their measurements.

Thus, Mariner's mission during the fly-by was to take measurements on two channels in the microwave region of the radio spectrum and two measurements in the infrared region of the spectrum. These two instruments were called the microwave radiometer and the infrared radiometer. They were turned on by radio command from the Goldstone Station of the Deep Space Instrumentation Facility on the morning of December 14 and immediately started to scan, even though the planet encounter was still six and one half hours away. The scan of the planet started at 2:59 p.m. (EST) and lasted until 3:34 p.m. (EST). The first scan was on the dark side, the second across the terminator and the third was on the light side. The instruments scanned in a nodding motion, up and down the planet, and the lateral motion was provided by the velocity of the spacecraft past the planet. The instruments continued to scan even though the planet had been left behind until the command was sent an hour later to return the spacecraft to its cruise mode, which had the effect of turning the radiometers off.

B. MICROWAVE RADIOMETER

The microwave radiometer scanned the surface of Venus at two wave lengths, detecting emissions from Venus at 13.5 and 19 millimeters. In the electromagnetic spectrum, 13.5 mm is the location of a microwave water absorption band. If water is present in the atmosphere of Venus above certain minimal levels, the readings from this instrument will be able to detect it. However, estimates of the water vapor content of the Venus atmosphere based upon Earth based observations in the near infrared region have indicated that the 13.5 mm radiation would not be controlled to any detectable degree by water vapor. The 19 mm wave length, however, is not affected by water vapor and was capable of penetrating the cloud cover and deeper atmosphere down to the surface or very close to the surface.

The 13.5 mm measurements would see the atmospheric radiation as well as that from the surface. Thus, the temperature determined from these measurements will be an average of hot temperatures near or at the surface, warm temperatures in the atmosphere above the surface and low temperatures from the high atmosphere. If the atmosphere is a strong microwave absorber, the radiometer operating at 13.5 mm will be able to see only into the upper layers of the atmosphere and will report temperatures colder than the average. In comparison, the 19 mm radiometer sees through the atmosphere directly to the surface, or close to it. Thus, the larger the temperature differences between the two radiometer measurements, the more water vapor is present in the atmosphere. In addition, the 19 millimeter wavelength was able to test two of the theories concerning the atmosphere of Venus by detecting one of two conditions called limb brightening or limb darkening.

One of the models of Venus postulated that Venus has an ionosphere with an electron density thousands of times that of the Earth. If this were true, it easily could have misled scientists attempting to compute Venus temperatures from Earth based radio measurements. The 19 mm wavelength measurement was able to show that Venus does not, in fact, have this super ionosphere. It did this by detecting the condition called limb darkening. Earth based measurements cannot accomplish this task.

As the radiometer scanned the planet, it looked through the least amount of atmosphere when it was pointed straight down in relation to the planet, and the most amount of atmosphere when it was pointed at the limb, or edge of the planet. This is analogous to looking at the Earth from thousands of miles in space on a day when the Earth is covered by a bright, glowing mist. The mist would be more evident at the limbs than in the center, since the observer would be looking at a thicker concentration of mist at the limbs. Thus, if a high electron density ionosphere, such as a radio "mist," had existed around Venus, the radiometer would have detected the condition called limb brightening as it looked through the greater concentration of electrons in the atmosphere at the edges of the planet.

The other theory--and the one which had been assumed by most scientists before the Mariner measurements--is that Earth based radio measurements are indeed explained by a hot surface on the planet. According to this theory, the atmosphere above the surface gets colder and colder with height, and there is not a high electron density ionosphere around Venus.

Looking at the planet from space, then, would be analogous to looking at a glowing hot Earth covered by dark and cool clouds. Looking straight down, one would see the hot surface, but looking toward the edge one would be looking through a thicker concentration of the cooler clouds, and might not see any of the hot surface. The edge, or limb, would appear darker. It was this condition, limb darkening, which was detected for the first time as it flew by Venus.

The microwave had a scan motion angular extent of 123.5 degrees and scanned at the rate of 0.1 degrees a second.

	Scan Number		
	1	2	3
Angular extent	About 10 degrees	About 15 degrees	About 10 degrees
Altitude at mid-scan	25,000 miles	23,500 miles	22,500 miles
Scan location	Dark side	Near terminator	Light side
Brightness temperature	370 degrees F.	570 degrees F.	260 degrees F.

Brightness temperature is calculated from a formula using the amount of light, or radio energy emitted by an object. In using this formula, it is assumed that the object is 100 percent efficient in emitting light--such as the Sun, for an example, or an ideal black body. But if the object is not a perfect light emitter--and most objects are not--then the light and radio energy is some fraction of that which would be emitted by a 100 percent efficient body, and the object really is hotter than the brightness measurement indicates. Thus, brightness temperature is the minimum possible temperature consistent with the measurements.

This means that the brightness temperatures observed by the microwave radiometer are lower than the actual temperatures that exist at or near the surface. It will take some time to reduce the brightness numbers to temperature numbers, but a preliminary estimate is that Venus has a surface temperature of approximately 800 degrees Fahrenheit at the terminator, which is probably closest to the average. Temperature readings from the edges also are affected by the limb darkening phenomenon.

The microwave radiometer weighed 23.8 pounds and required 3.5 watts of power during its operation and 8.9 watts during the periods when it was calibrated.

The experimenters, are Professor A. H. Barrett, Research Laboratory of Electronics, Massachusetts Institute of Technology; Jack Copeland, Ewen Knight Corporation; D. E. Jones, Brigham Young University/JPL; and Professor A. E. Lilley, Harvard College Observatory. An important contributor was F. T. Barath, California Institute of Technology Jet Propulsion Laboratory.

C. INFRARED RADIOMETER

The infrared radiometer is a companion experiment to the microwave radiometer and the data obtained from it are being correlated with the microwave radiometer data. The IR radiometer was rigidly attached to the microwave antenna so that both systems scanned the same areas of Venus.

The IR radiometer was designed to detect emissions from Venus at 8.4 and 10.4 micron wavelengths of the spectrum. Measurements from Earth taken at these two wavelengths indicated temperatures below zero, but it was not clear from the data whether all of this radiation came from the cloud tops or whether some of it emanated from the atmosphere or from the surface through cloud breaks.

For many years, some astronomers have been able to observe some kind of markings in the Venus cloud cover that change with no apparent regularity. The lack of regularity in these markings has left their nature in doubt. If these markings are indeed cloud breaks, they will stand out with greater contrast in the infrared than if observed in the visible part of the spectrum. If the radiant energy detected comes from the cloud tops and there are no breaks, then the temperatures obtained at both infrared wavelengths will follow a similar pattern. If there are appreciable breaks in the clouds, a substantial difference will be detected between measurements at the two wavelengths. The reason for this is that in the 8 micron region, the atmosphere is transparent except for clouds. In the 10 micron region, however, the lower atmosphere is hidden by the presence of carbon dioxide. Through a cloud break, the 8 micron emission would penetrate to a much lower point in the atmosphere.

Preliminary analysis of the data from both wavelengths of the IR radiometer gives approximately the same temperature at all points. This suggests that both channels saw down to the same depth in the Venus clouds, indicating that both channels were looking at a thick, dense cloud layer opaque to infrared radiation. If there had been breaks in this cloud mass, the 8 micron channel would have seen down to a deeper, hotter region, but the view of the 10 micron detector would have been stopped at a higher altitude by the carbon dioxide in the Venus atmosphere. From earth based measurements, it is known that carbon dioxide is an important constituent of the Venus atmosphere. The amount of carbon dioxide above this cloud layer--which was opaque to the infrared channels--was too small to be detected by the Mariner instruments.

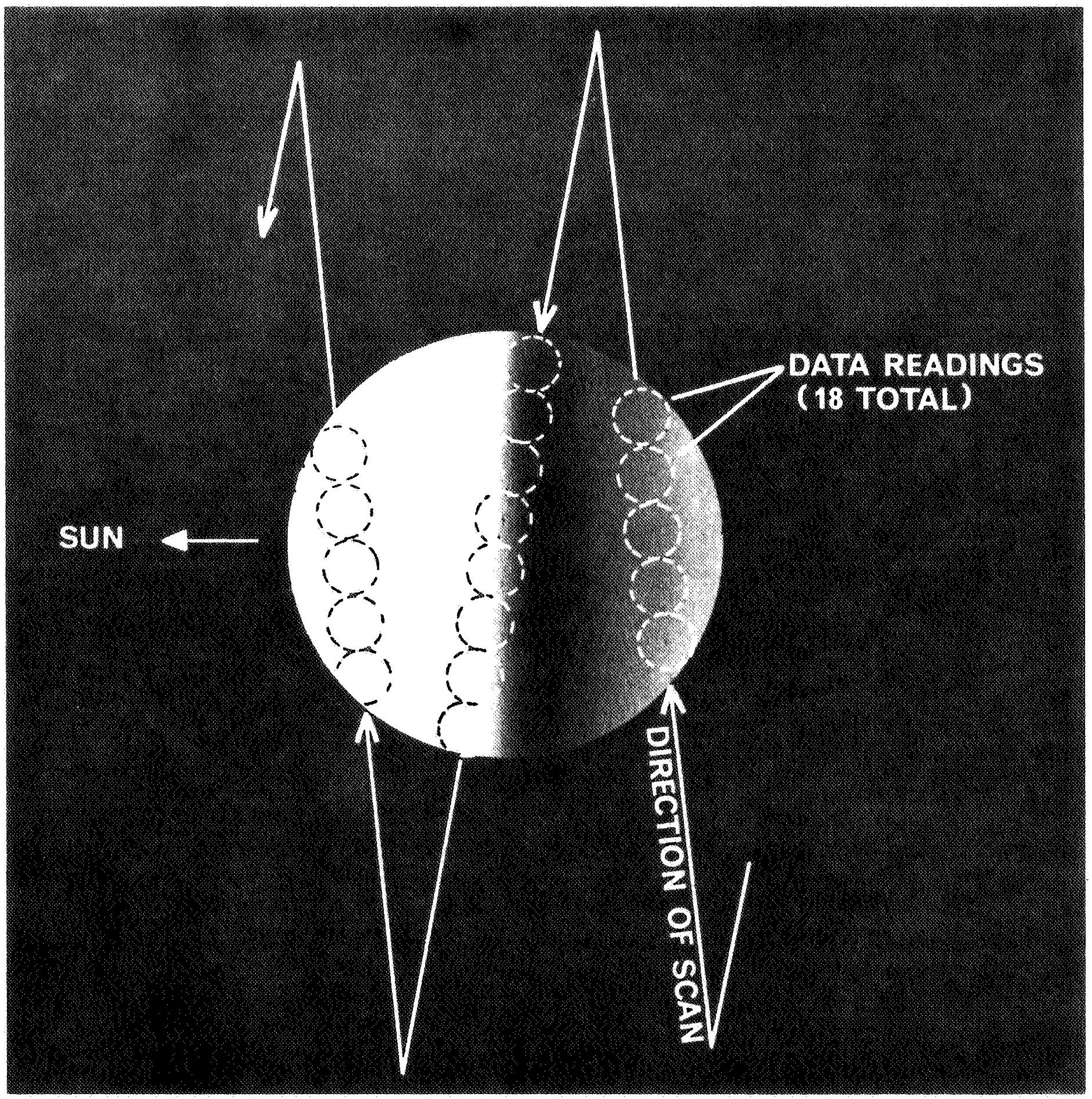
The IR instruments observed limb darkening, as did the microwave radiometer, and for a similar reason. This observation indicates that the cloud layer is thick and somewhat translucent to infrared--like a thin fog is translucent to ordinary light. In that part of the scan in which the IR radiometer looked down at the center of the planet, it could see a deeper, hotter and brighter part of the cloud layer, but at the limb of the planet the sensors were looking edgewise through the cloud, and could not see so deeply. Only the upper cooler and darker portion of the cloud layer was visible. One can compare this to the phenomenon that occurs on a foggy day when by looking straight up the sky is blue but when looking along the horizon the fog is gray and dense.

The IR measurements produced a curious result. Toward the south end of the terminator, the temperatures on both channels showed a cold spot on Venus, about 20 degrees Fahrenheit cooler than the rest of the cloud layer. This means that the clouds in this region are higher, or more opaque, or both. An interesting possibility is that this cooler section of the cloud layer is associated with some hidden surface feature. This cold spot was the only anomaly observed.

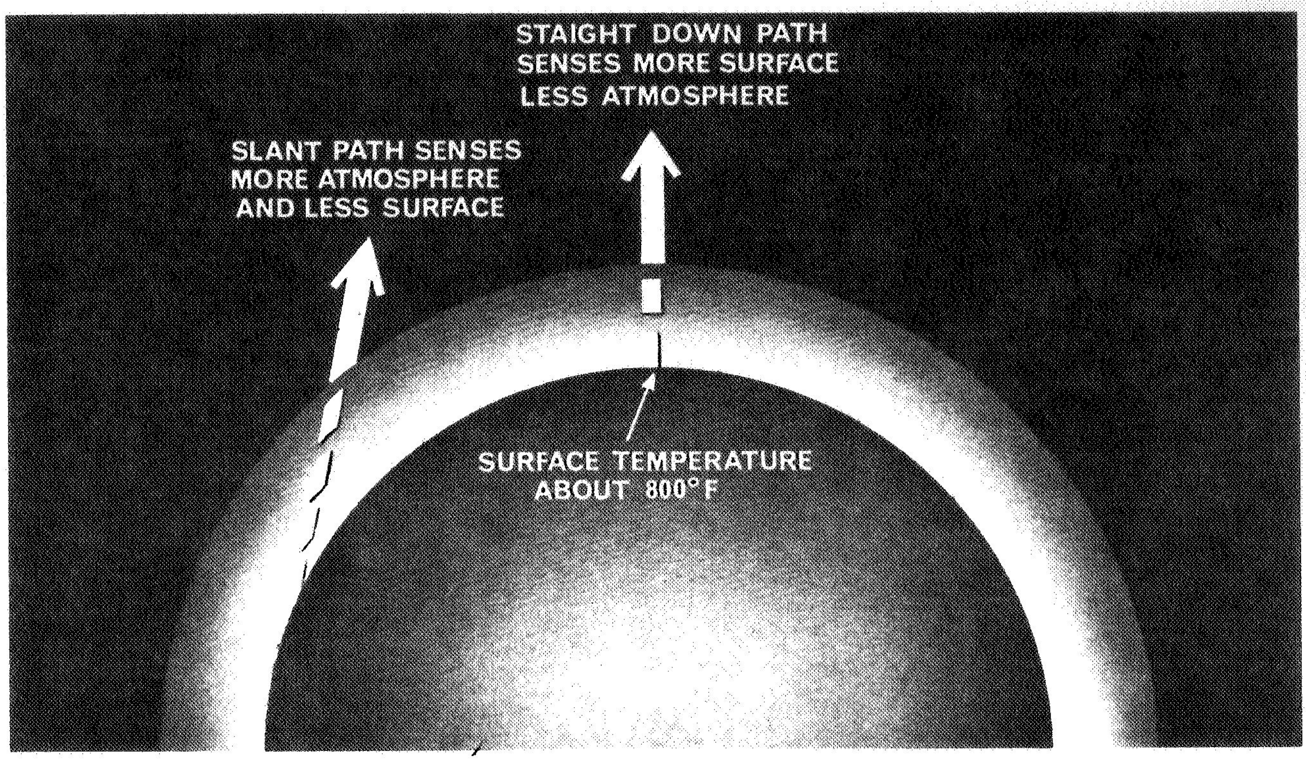
Temperatures in the cloud layer were the same on the dark side as on the light side. At the center of the planet, the temperature was measured at about minus 30 degrees Fahrenheit, but the certainty of this value must await further data evaluation.

The infrared radiometer was approximately a 5 inch cube. It weighed 2.7 pounds and used 2 watts of power in its operation.

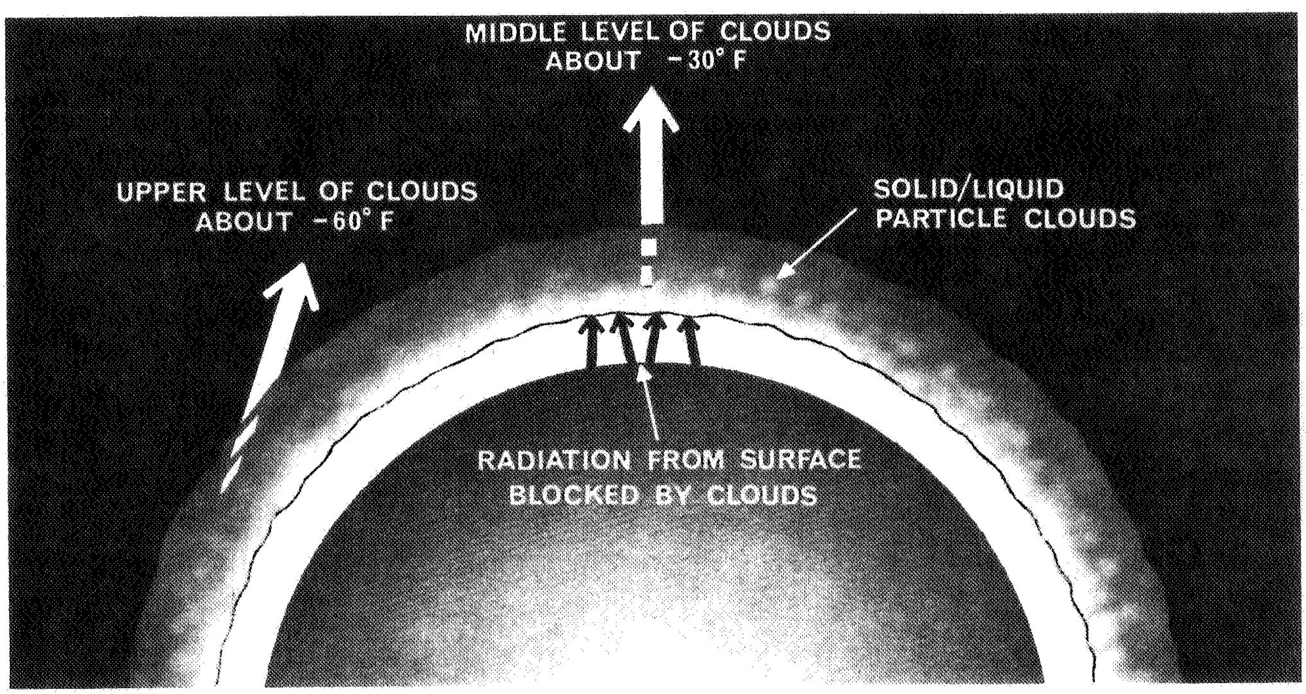
The experimenters are Dr. L. D. Kaplan, University of Nevada/JPL; Dr. Gerry Neugebauer, Caltech/JPL. An important contributor was S. C. Chase, Caltech/JPL. Dr. Carl Sagan, Harvard College Observatory was an active participant during the conception and planning of the experiment.



Mariner 2 Radiometer Scans of Venus



Mariner 2 Microwave Temperature Study of the
Venus Atmosphere and Surface



Mariner 2 Infrared Temperature Study of the Clouds of Venus

D. FIELDS AND PARTICLES EXPERIMENTS

The eight fields and particles sensors which were carried on Mariner 2, have produced an unprecedented quantity of high quality data on the nature of the interplanetary medium. The Mariner data, for example, indicating that solar gas continuously flows out from the Sun at great speeds appears to settle a 30-year old scientific controversy. During the 129 days between launching and the final loss of radio contact with the spacecraft, fields and particles data were actually recorded by the tracking stations for approximately 104.1 days.

Radio signals from the Mariner spacecraft were heard for the last time by the Deep Space Instrumentation Facility station in Johannesburg, South Africa, at the conclusion of its acquisition period at 2:00 a.m., EST, on January 3. At that time, the spacecraft was 53.9 million miles from Earth, 5.6 million miles beyond Venus, and had traveled 223.7 million miles since launch on August 27.

Data were recorded without interruption for one period of 38.3 days and for three other periods of greater than nine days. Nothing approaching this continuous long-term coverage of a distant space probe has ever been achieved before, and such coverage is of great value for experiments which are attempting to discover the temporal and spatial variations in interplanetary phenomena.

The eight fields and particles sensors included three to measure magnetic field components, three to count cosmic-ray particles, one to measure the ionization produced by cosmic rays, and one to measure the energy and quantity of solar plasma (positively-charged atomic particles with very low velocities).

The scientists in charge of the magnetometer were Mr. Paul J. Coleman of the University of California at Los Angeles, Professor Leverett Davis, Jr., of the California Institute of Technology, Dr. Edward J. Smith of the Jet Propulsion Laboratory, and Dr. Charles P. Sonett of the Ames Research Center of NASA. This instrument measured each of three components of the magnetic field approximately 240,000 times during the mission.

The cosmic radiation, of both solar and galactic origin, was monitored by three omnidirectional detectors and one unidirectional detector. The omnidirectional detectors--an ionization chamber and two Geiger counters--were the responsibility of Dr. Hugh R. Anderson of the Jet Propulsion Laboratory and Professor H. Victor Neher of the California Institute of Technology. The unidirectional detector--a small Geiger counter of a type which has been used extensively in the exploration of the Van Allen belts of trapped radiation around the Earth--was the responsibility of Mr. Louis A. Frank and Professor James A. Van Allen of the State University of Iowa. Two of the Geiger counters sampled the particle flux every 7.4 minutes, thus making more than 10,000 measurements during the mission, and the third one operated at twice this sampling rate. The ionization chamber was in continuous operation, and gave an integrated reading about every 6.3 minutes.

The solar plasma experiment, for which the experimenters were Mrs. Marcia Neugebauer and Dr. Conway W. Snyder, made successive measurements of the plasma flux at ten different energy intervals. It required 3.7 minutes to acquire a complete energy spectrum of the plasma, and approximately 40,000 such spectra were obtained.

During the encounter with Venus, the fields and particles experiments collectively were designed to investigate the extent and nature of the magnetosphere of the planet on its Sunward side. The magnetosphere of the Earth is the region within which the geomagnetic field is confined, and where magnetically trapped radiation is found. It has been investigated by various instrumented satellites and space probes to the extent that its general features are known making it possible to predict what Mariner might see if it penetrated the magnetosphere of Venus. Near the boundary of the magnetosphere, the magnetic field should change rather drastically in direction and magnitude from its interplanetary values, and rather large fluctuations in the field would be expected for considerable distances outside the boundary. The cosmic-ray instruments would detect trapped radiation inside, but should see only the interplanetary cosmic-ray background outside. Also the solar plasma should disappear as the spacecraft passed inward through the boundary.

The earth's magnetosphere on the Sunward side usually extends about 40,000 miles out, and it would be clearly detectable by the Mariner instruments. If the Venus magnetic field were similar to that the the Earth, at an altitude of 21,600 miles (the closest approach of Mariner to Venus), the magnetic field would be 100 to 200 gammas, the counting rates of the cosmic-ray instruments would be large (up to about 3,000 per second for the unidirectional counter near the equator), and no solar plasma would be seen.

In sharp contrast, however, all the fields and particles instruments continued to produce their interplanetary readings as Mariner coasted by Venus. The magnetometer saw no unusual changes in the field which exceeded its 5-gamma limit of sensitivity. The unidirectional Geiger counter continued to register 2 counts per second, and the other radiation detectors also saw no change. The solar plasma velocity increased very slightly as the planet was passed, but showed no unusual behavior.

These results confirm qualitatively some of the theoretical ideas which are generally accepted regarding the source of planetary magnetic fields and the nature of field-plasma interactions. The strength of a planetary field is believed to be closely related to the rate of rotation. Other experiments have shown that Venus appears to rotate very slowly, and thus would be expected to have a small field. The size of a planet's magnetosphere is determined by the equilibrium between the pressure of the solar plasma pushing inward and the expansive pressure of the magnetic field of the planet. At Venus, the plasma pressure must be somewhat greater than at the Earth, because of the closer proximity of the Sun, and this fact coupled with a smaller magnetic field would indicate that the magnetosphere of Venus might be considerably smaller than the Earth's.

The data does not show that Venus has no magnetic field (although such might be the case), but only that the field did not extend out to the Mariner orbit. An upper limit can be estimated by utilizing the theory of field-plasma interaction, together with what is known about the Earth's magnetosphere. The Mariner scientists conclude that the magnetic dipole moment of Venus, if it is approximately perpendicular to the Sun-Venus line, is less than five to ten percent of that of the Earth. If Venus has the kind of simple magnetic structure as the Earth, the magnitude of the surface field is less than five to ten percent of the Earth's field at the surface (about 30,000 gammas near the equator and 50,000 gammas near the poles). If Venus has a complicated magnetic structure, then the surface field in places might considerably exceed the Earth's without increasing the field along the Mariner trajectory to an observable value.

The very large volume of interplanetary fields and particles data are still being intensively studied and compared with other information from similar experiments in satellites and on Earth. This process will certainly continue for months. A very small fraction of the data have not yet been deciphered from the magnetic tape records of the tracking and telemetry stations. Only preliminary conclusions are, therefore, available at this time. Nevertheless, some significant results have been obtained.

Perhaps the most interesting new information is the demonstration that solar plasma flowing radially out from the Sun was detectable in every one of the 40,000 spectra obtained in the four-month mission and hence, presumably, is always present. This plasma flow, sometimes called the "solar wind" had been suspected for some time, having been postulated to explain the motion of certain comet tails and the occurrence of geomagnetic storms, and it had been measured for short periods by the American space probe Explorer X and by several Russian probes. The Mariner 2 measurements are both more detailed and vastly more extensive than previous measurements.

The solar wind had been explained theoretically as a continuous expansion of the solar corona, the tenuous, extremely hot, outer atmosphere of the Sun. The Mariner results show that the velocity of this expansion (if such is the mechanism) undergoes frequent fluctuations, which probably reflect the inhomogeneity of the solar surface. Approximately 20 occasions were seen when the velocity increased within a day or two by amounts from 20 to 100 percent. The fluctuations correlate very well with the amount of magnetic disturbance observed on the Earth, and in several cases sudden and sharp increases in the density, velocity, and temperature of the plasma preceded the onset of sudden magnetic storms on Earth. The time delay corresponds to the fact that Mariner was, at all times, inside the Earth's orbit, so that the outward moving plasma cloud would generally reach the spacecraft first.

The velocity of the observed solar wind varies from 200 to 500 miles per second approximately, and its temperature is in the neighborhood of a million degrees Fahrenheit. Thus, it resembles the blast out of a rocket nozzle more than it resembles a wind. It is like a rocket blast also in that its velocity is greater than that of a typical wave motion in a plasma (called an Alfven wave), so that its flow is, in this sense, "supersonic". On the other hand, its tenuosity is almost beyond comprehension, there being normally only about 10 to 20 protons (hydrogen nuclei) and electrons per cubic inch.

The presence of the solar wind drastically alters the configuration of the exterior magnetic field of the Sun. The solar plasma carries along with it lines of magnetic force which originate in the corona. The frequent variations in plasma velocity result in the deformation of these field lines, so that it is difficult to deduce what the general undisturbed configuration of the solar field would be from the point-by-point measurement of the magnetic field. Mariner 2 showed that the field transverse to the radial direction from the Sun is typically from 2 to 5 gammas at quiet times, and shows some tendency to have its direction approximately parallel to the plane of the Earth's orbit. An appreciable component perpendicular to the orbit exists much of the time and fluctuations of 10 to 20 gammas or even more are not uncommon. Such large fluctuations usually correlate with changes in the plasma flow. (For comparison, the Earth's magnetic field is approximately 30,000 gammas at the equator and 50,000 gammas at the poles.) It is hoped that further detailed analysis of the magnetic data may reveal the presence of magnetic waves in space and clarify the interactions between the magnetic field and the plasma.

The omnidirectional cosmic-ray detectors measured a fairly constant flux throughout most of the flight, indicating that they were detecting galactic cosmic rays. The fact that the flux encountered by the spacecraft did not change even with a 30 percent decrease in the distance between Mariner and the Sun, is of considerable theoretical interest in connection with the understanding of the spatial and temporal variations of the cosmic rays.

The walls of the omnidirectional detectors were equivalent to 0.01 inch of steel, so that they responded to protons with energies above 10 million electron volts (mev) and electrons above about 0.5 mev. Results from Mariner compared with those obtained from balloon-borne instruments are of interest. Measurements made in the Mariner ionization chamber alone tell nothing about the distribution of energies of particles that do penetrate the wall. The following may be deduced by comparing Mariner with Thule, Greenland, balloon flights. Balloon measurements showed a scarcity of primary protons below about 800,000,000 electron volts of energy at this phase of the solar cycle. The fact that cosmic rays in space are even less than that deduced from measurements at the poles confirms this scarcity of particles at distances far from the Earth. In fact, one may draw the conclusion that, at the time Mariner was collecting data, there were very few, if any, particles except for one burst of particles ejected from the Sun, in the energy range 10 to about 800 mev for protons. Solar cosmic rays were detected clearly on only one occasion, on October 23 and 24, when the number of particles detected in each sampling interval increased for a time by more than a factor of five. A comparision of the response of the three detectors indicates that the particles in the stream were primarily protons with energies near 25 mev. Thus, a very modest increase in the wall thickness of detectors would have excluded the particles almost entirely. The proton flux exhibited some very interesting time variations, which will be further studied.

This event was a very tiny one as solar proton events go. The total radiation dose inside the ionization chamber amounted to only about one-fourth roentgen. During the entire mission the dose was only about 3 roentgéns predominantly from very penetrating particles. Since an astronaut could almost certainly accept doses of 30 to 50 or perhaps even 100 times this amount over a four-month period without serious effects, it appears that space posed no radiation hazard to any space travelers that may have been abroad last autumn.

In contrast to the omnidirectional detectors, the Iowa unidirectional counter saw not only the October 23 event, but at least seven other smaller bursts of radiation during September and October. The nature of the radiation has not been positively identified from the information at hand, but it may consist of protons between 0.5 and 10 mev or electrons between 0.04 and 0.5 mev, as it was not seen by the thicker-walled omnidirectional detectors.

In summary here is a picture of ionized particles in interplanetary space. From a few hundred to 1,000 electron volts, particles are numerous. Something like 100,000,000 strike a square centimeter a second. In the range, 0.5 to 10 mev for protons, very few exist at times but at other times their flux may be a number of times that of cosmic rays. In the range of energies 10 to 800 mev for protons, there is a nearly complete absence of particles normally. During a solar burst, the number of particles in this energy range may be very large. Above 800 mev, galactic cosmic rays enter interplanetary space and these decrease in number quite rapidly as the energy increases, the total number of such particles being about 3 per centimeter per second. An energy range not investigated at all but which may be important, i.e., the range of proton energy from about 10,000 to 500,000 electron volts.

During a 30-day period during November and early December, the unidirectional counter detected only two very small increases in the radiation intensity. It is interesting that during this period the mean velocity of the solar wind was considerably lower than it had been during September and October when the counter was detecting frequent bursts of radiation. This fact suggests that the sources of high-velocity plasma clouds and of the low-energy solar cosmic rays may be identical or related in some way.

E. COSMIC DUST EXPERIMENT

The cosmic dust experiment on Mariner 2 was designed to measure the flux of interplanetary dust particles between the Earth and Venus. The system was capable of detecting dust particles with masses as low as 1.3×10^{-10} gm (about one trillionth of a pound). Over 1700 hours of reduced data have been received. During this time two dust particle impacts on the sensor plate were recorded. The dust particle flux indicated by this measurement is approximately four orders of magnitude less than that observed near the Earth from similar experiments on satellites. Both of the above events occurred in deep space, and no impacts were recorded in the vicinity of Venus.

The experimentor is W. M. Alexander of the Goddard Space Flight Center.

F. RADIO TRACKING

Precise two-way doppler tracking of Mariner 2 during its 130-day flight to Venus and beyond has provided scientists with basic information that will help further refine physical constants that are important in understanding the solar system and the earth. Using the data obtained, the scientists will be able to apply themselves to getting, with more certainty than now available, such figures as:

(1) The mass of Venus.
(2) The precise location of tracking stations on the Earth.
(3) The value of the Astronomical Unit. (The AU is the mean distance between the Sun and the Earth.)
(4) The mass of the Earth's Moon.

The high accuracy and great volume of Mariner tracking data will serve as a stimulus to workers in celestial mechanics to combine radio tracking data, radar astronomy data and optical data. The long term results of such a combination will resolve existing incompatibilities in experimental results and dramatically advance our ability to describe the mechanics of the solar system. This clearly is needed for accurate navigation ang guidance for more advanced missions.

Before the Mariner mission, it was suspected that uncertainties in some of the solar system physical constants--such as the AU--would make it difficult, if not impossible, to use ground based radio guidance techniques to command a spacecraft to hit a planet. It was suspected that it would be necessary to use some sort of "homing" device on the spacecraft so that it could "sense" the planet and home in on it. Now it appears that simpler Earth based radio guidance techniques will remain competitive to on board guidance measurements and computation techniques until extremely precise target error control is desired. For example, on December 7--one week before the Mariner encounter with Venus--the position of the spacecraft with respect to Venus was uncertain to only 800 miles--mostly due to the positional uncertainty of Venus with respect to the Earth. Now, as the precise tracking data have been analyzed, it is possible to reconstruct the position of the spacecraft with respect to Venus to within 10 miles at encounter. Closest approach of Mariner with respect to Venus was 21, 648.

More than 22, 000 two-way doppler data points were taken during the 130-day Mariner mission, and it is the volume and precision of these data points that are proving so useful in refining the trajectory. Two-way doppler is a precise method of measuring radial velocity of a spececraft by using the well known doppler shift in frequency in a radio signal between two moving objects. This effect is what causes the sound of a train whistle to rise in pitch as the train approaches and drop in pitch as it passes. Two-way doppler is an extremely precise method of determining the shift in the radio signal frequency.

In the Mariner mission, the Goldstone tracking station of the Deep Space Instrumentation Facility transmitted a signal to Mariner. The signal, received at the spacecraft, was shifted in frequency by the doppler effect, and then was retransmitted by the spacecraft to Goldstone. The signal received at Goldstone was further shifted by the velocity of the spacecraft in relation to the station. Velocity changes so precise as to be on the order of one tenth of one inch per second were measured by this two-way doppler tracking. Using these data, it was possible to calculate exactly how the Mariner trajectory was perturbed by the gravity of Venus as Mariner flew by Venus.

The size of this perturbation and the accuracy of its determination, then, is extremely useful in determining the mass of Venus. Classical astronomers, using data on the perturbation of the orbits of other celestial bodies caused by Venus and collected over several decades, have calculated the mass of Venus to be 0.8148 of the mass of the Earth. The probable error is 0.05 percent. The Mariner data--collected over two weeks, one week before and one week after encounter--has a potential to determine the Venus mass with a probable error of 0.005 percent.

Another significant result obtained was the absolute location of the Goldstone station. Before the Mariner mission, the exact location of the Goldstone station had been known to within 100 yards. After Mariner's data have been analyzed it will be known to within 20 yards.

The way the station location is determined from the doppler data may be understood by supposing the spacecraft to be fixed in space with respect to the center of the Earth. The only doppler tone observed would be caused by the station's rotational velocity component along the direction to the spacecraft. The observed doppler tone at the station depends, then, on the latitude, longitude and radius from the center of the Earth. Since many measurements were obtained during many passes at the DSIF stations, it will be possible to deduce the proper combination of station location errors to match the data.

The mass of the Moon may be determined by similar reasoning from the data. In this case, the variation in doppler tone is due to the movement of the Earth around the Earth-Moon system's center of mass, or barycenter. The Earth makes one revolution around this barycenter every 28 days at a speed of 27 miles an hour.

Of the three items that influence this motion--the Earth's mass, the Moon's mass and the Earth-Moon distance, the Moon's mass is the least well known. The Moon's mass is now known to a certainty of 0.1 percent. The scientists hope that by analyzing the data it may be possible to reduce this present uncertainty to a smaller figure.

The Astronomical Unit--the mean distance between the Earth and the Sun--is used as the yardstick of the solar system. Data from classical astronomical observations have derived a value of the AU which is 50,000 miles different from the value derived by Venus radar bounces in 1961. The radar-established AU is 92,956,200 miles, plus or minus 310 miles. The optical AU is 50,000 miles smaller.

A similar Venus radar bounce, conducted by the Venus station at Goldstone during the Mariner mission, produced the same result as the 1961 bounce also conducted at Goldstone. The Mariner tracking data now provides an additional radio determination which will help resolve the conflict between the radar established AU and the AU calculated by optical measurements.

The results were reported by Thomas W. Hamilton, chief of the systems analysis section of the California Institute of Technology Jet Propulsion Laboratory, and Donald W. Trask, supervisor of the orbit determination group of the same section at JPL.

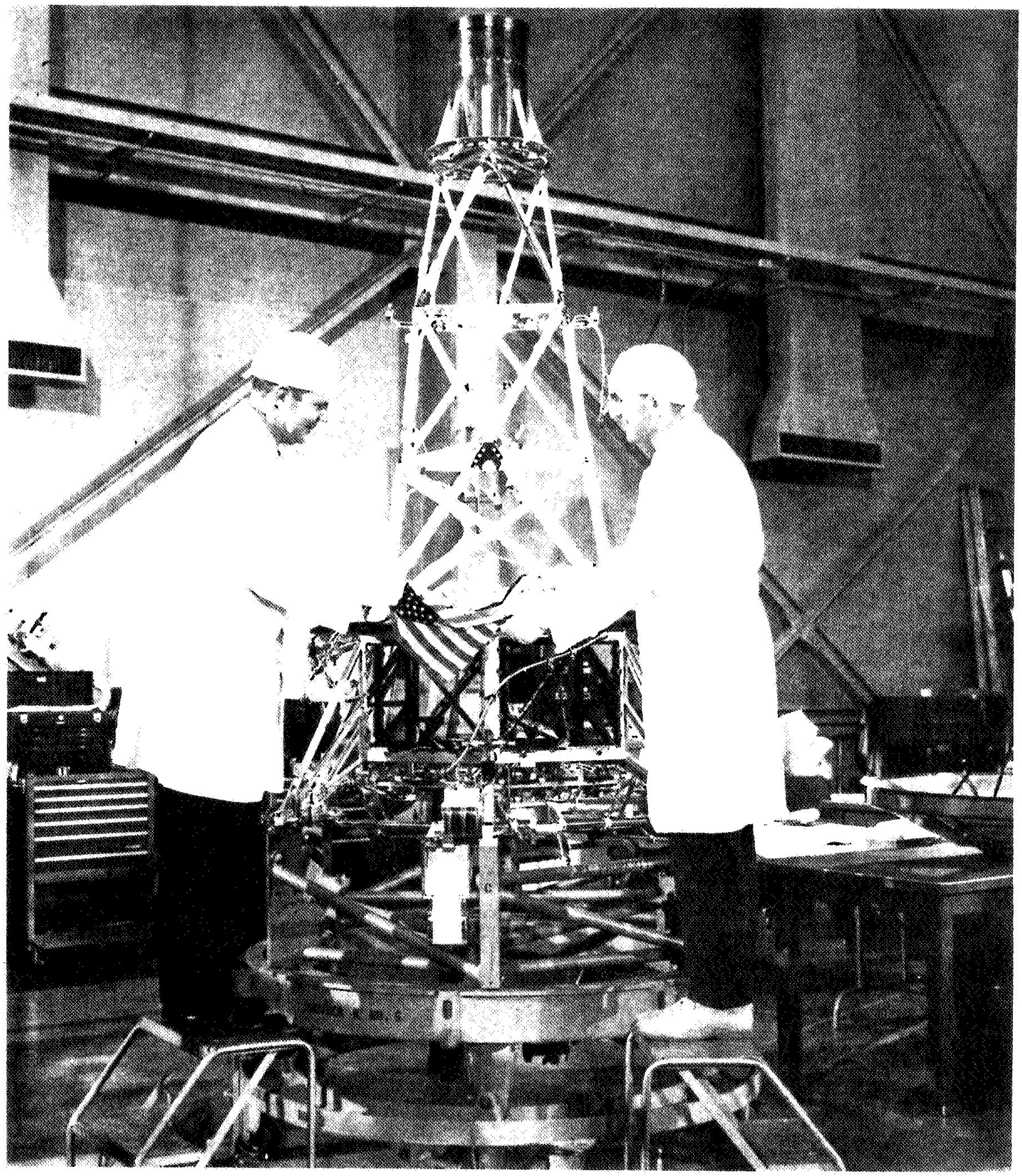
G. DEEP SPACE TELECOMMUNICATIONS

Two major telecommunication activities were in process during the Venus encounter of 1962. The first, and by far the largest, activity involved the two-way communications and tracking of the Mariner spacecraft from the DSIF stations on the Earth. The DSIF includes stations at Goldstone, California; Woomera, Australia, and Johannesburg, South Africa. The second activity involved an Earth based radar which reflected signals off of the planet Venus during the same month that the Mariner spacecraft was traveling toward the planet.

Communications between the Mariner spacecraft and the DSIF on the Earth have resolved several questions of considerable importance for future deep space exploration. It is now known that reliable deep space communication to and from spacecraft is possible within the solar system, certainly to distances of 53 million miles, without significant disturbing effects from space itself. We now know that extremely precise tracking is practical in deep space, particularly of the radial velocity of the spacecraft from the Earth, and have demonstrated that on the order of one-tenth of an inch per second in radial velocity can be measured to distances of at least 53 million miles. Radial velocity is the velocity of the spacecraft away from the Earth.

By the technique of using directional antennas on fully stabilized spacecraft and extremely sensitive equipment on the Earth, it has been proved possible to acquire great quantities of data during the long deep space flights. The Mariner 2 flight resulted in accumulation of some 65 million bits of information with an accuracy of at least one percent and yet with the use of only 3 watts of radio frequency power. A new technique for precise synchronization of telemetry and communication channels using pseudorandom codes successfully demonstrated that precise synchronization is possible using only very low powers.

The Mariner flight also demonstrated the utility of the basic design of the DSIF as a world wide network of cooperating stations which can keep continuous, 24-hour a day, contact with the spacecraft, transmit the data to California, and have it available to experimenters in a relatively short time. Some 85 percent of the data transmitted from the spacecraft was available to the experimenters within one hour of reception at the Earth and some 98 percent of the data was accurately recorded for future use.



J. N. James, Mariner Project Manager, and D. W. Lewis, Thermal Engineer, are shown placing the American Flag under the thermal shield of the United States Venus spacecraft

APPENDIX A

TRANSCRIPT OF THE NEWS CONFERENCE ON THE MARINER 2 SPACECRAFT FLY-BY OF THE PLANET VENUS 14 DECEMBER 1962

PARTICIPANTS:

MR. JAMES E. WEBB, Administrator, NASA.
DR. HUGH L. DRYDEN, Deputy Administrator, NASA.
DR. ROBERT C. SEAMANS, JR., Associate Administrator, NASA.
DR. HOMER E. NEWELL, Director, Office of Space Sciences, NASA.
DR. WILLIAM H. PICKERING, Director, Jet Propulsion Laboratory.
MR. EDGAR CORTRIGHT, Deputy Director, Office of Space Sciences.
MR. FRED KOCHENDORFER, Mariner Project Manager, NASA.
MR. ORAN NICKS, Chief of Lunar and Planetary Programs, NASA.
MR. JACK N. JAMES, Jet Propulsion Laboratory.
SENATOR ROBERT S. KERR, Chairman, Committee on Aeronautical and Space Sciences, United States Senate.
SENATOR MARGARET CHASE SMITH, Ranking Minority Member of the Committee on Aeronautical and Space Sciences, United States Senate.
CONGRESSMAN JOSEPH E. KARTH, Chairman, Subcommittee on Space Sciences, Committe on Science and Astronautics, House of Representatives.
MR. RICHARD T. MITTAUER, Public Information Officer, NASA.

SEAMANS: This news conference will now convene.

One hundred and nine days ago Mariner left Cape Canaveral. Now Mariner 2 is 36 million miles from Earth, traveling at a speed of 15,000 miles per hour towards Venus.

We are currently scanning and gathering data from the planet. You will hear signals which are received from Mariner 2, both at 2:30 and at 3:00 o'clock here this afternoon.

As 3:01 the Mariner 2 will be at its closests point to the planet.

What we have here is a national effort which involved the NASA, JPL, the Air Force, and a number of contractors.

We have here on the stage people who are particularly responsible for this important mission. They are, going from your left to your right, Dr. Homer Newell, who is the Director of the Office of Space Science, responsible for the mission here at Headquarters;

Congressman Joseph Karth, representing Congressman George Miller, who is Chairman of the House Committee on Science and Astronautics, and who himself is Chairman of the Subcommittee responsible for this program ;

Dr. Hugh Dryden, who is the Deputy Administrator of the NASA;

Senator Kerr, Chairman of the Senate Committee on Aeronautical and Space Sciences;

Mr. Webb, Administrator of NASA;

Senator Smith, a leading member of the Senate Committee on Aeronautical and Space Sciences, and about to become the leader of the minority party;

Dr. Pickering, Director of JPL; and Mr. Cortright, Deputy Director of the Office of Space Science.

The first speaker here this afternoon will be Mr. Webb.

WEBB: Thank you, Dr. Seamans.

I would like to start by saying that we are here this afternoon to share a significant hour, one in which more may be added to man's knowledge of the planet Venus than has been gained in all the thousands of years of recorded history. By comparing our measurements of the physical characteristics of Venus with those of the Earth, we may open new areas of understanding of our mother Earth. It is an hour, I suspect, which all of us will one day find ourselves sharing with our grandchildren, recalling how we today participated in an historic scientific event, even though we are 36 million miles away.

During this hour you will hear from some of those to whom we owe this outstanding "first" in space for our country and for the Free World. If all goes well, you will also hear from Mariner 2 itself, as it makes its closest approach to Venus on its way to an orbit around the Sun, and as it beams back the precise measurements to Earth, across the vast reaches of interplanetary space.

In the short time we have, it is not possible for me to adequately describe the tremendous contributions to Mariner 2 of men like Dr. Hugh Dryden, Dr. Robert Seamans, Dr. William Pickering, and Dr. Homer Newell, who are here, and to whom you may address your questions later. Many others in government, in universities and industry have also contributed.

The brilliance of the scientific, technical and administrative effort which has gone into this program is already evident in the knowledge which has been obtained from the Mariner flight, and which will more than justify this flight, no matter what we obtain as it passes Venus in the way of measurements.

Now it is necessary that I dwell on the contribution of the members of the Senate and House space committees who are here, Senator Robert S. Kerr, Senator Margaret Chase Smith, Congressman Joseph E. Karth, or their associates in the Congress. Again, the success of this effort is a testimonial to the strong bi-partison support which has been provided for our program.

This event is one part of a broad, balanced program for scientific investigations in space. Although Mariner 2 is the most significant, and perhaps the most spectacular, of our scientific efforts to date, it is but one of a number of important investigations designed by our nation's ablest scientists to add to our knowledge of the universe. The knowledge gained from these basic research efforts will not only contribute to our immediate objectives in space, not only bear directly on our lives here on Earth, and our military security, but is vital if we are to continue on toward more advanced goals.

It is also important, I believe, to view this event as an example of the growing interdependence of the scientist and of the engineer. Creative engineers have used what science has already learned to design instruments which can move ever farther into the hostile environment of space so that the scientists in turn can learn even more.

And, as the scientist and the engineer depend increasingly on each other, so will all of us depend increasingly on them. Our future is inextricably entwined with what they learn and how we use it. Scientific knowledge, technological skill, and their applications by the entrepreneurial mind, our industrial leaders, henceforth will determine the pace of economic growth.

And, finally, Mariner 2 and this very meeting here today are an example of one of the essential characteristics of the United States space program. What is learned about Venus today, or if we learn nothing, is being shared with all men and all nations, to insure maximum progress in science not only in the United States, but throughout the world.

This is the premise on which such a complex, far-sighted, and spectacular national effort as our United States space program was established by legislation, openly debated and hammered out through our normal governmental processes, by a Congress which wisely foresaw that the peaceful exploration of space for the benefit of all mankind would bring the greatest benefit to our own nation as well. As one member of the Senate committe, which passed this legislation put it -- and I am quoting him:

"I am convinced that the nation which leads in exploring and using space for peaceful purposes can best build, improve, and inherit the Earth."

The author of that statement, now Chairman of the Senate Committee on Aeronautical and Space Sciences, is with us today to express the continuing interest and support in the space science part of our effort as well as in the manned space flight part. He is a man who wants to see what the nation gets for its dollars, and I suspect is here today also partly for that purpose.

But before I introduce him, I would like to say first that President Kennedy would like very much to have been here today. He had a previous commitment, as you all know, outside the city which made it impossible. He has expressed the keenest interest in this program.

And I have a very short message from Vice President Lyndon Johnson, who is, as you know, the Chairman of the Space Council, and was very instrumental in the passage of this legislation, has been continuingly a strong and vigorous advocate of space power for the United States. This is his message:

"By its historical flight, Mariner 2 has further extended the frontiers of space. This great feat is another plus for America's prestige, and, even more, it is added evidence of the scientific breadth and vigor of our national space program. Congratulations to all those who have contributed to this major success. Lyndon Johnson, Vice President of the United States."

Now I should like to introduce Senator Robert S. Kerr, the senior Senator from Oklahoma, and the Chairman of the Senate Committee on Aeronautical and Space Sciences.

Senator Robert Kerr.

SENATOR KERR: Thank you very much, Jim Webb. This is a great day for you, for Dr. Dryden, Dr. Seamans, for your entire National Aeronautics and Space Administration throughout the country who have made this tremendous accomplishment possible.

It is also a great day for the United States and for free men everywhere.

The event which we note here is a very important achievement of American science and technology, but it has significance far beyond that. The skill which made it possible demonstrates the power of the space team which had been and is being built in the United States.

It demonstrates the wisdom of President Kennedy and the Congress in emphasizing the importance of a strong and vigorous space program. We have such an effort now, and we intend to continue to improve it in every phase of space research and exploration.

As one who participated in the creation of the National Aeronautics and Space Administration in 1958, I can not help contrasting this moment with our situation five years ago in December of 1957. At that time the space successes which interested and most concerned us were the orbiting of Russian Sputniks I and II, and the failure of the first three-stage Vanguard to place a U.S. satellite in orbit. This recollection must, for all uf us, add to the pleasure of being here today.

As Chairman of the Senate Space Committee I am gratified by this new demonstration of the success of American efforts to do important scientific research in space for the benefit of the citizens of our country and of every other human on the face of the Earth. I know that every American shares this pride.

We have come a long way in the last five years, and when I say "a long way" I speak not only of the hundreds of millions of miles these satellites have traveled, but of substantial progress in all forms of space exploration which will have a significant effect upon us all.

Progress in space is neither cheap nor easy. Few important things in this world are. But progress in space is an absolute necessity if we are to remain the strongest nation in the world and a free nation capable of leading the Free World and capable of exercising that leadership for the good of all mankind.

That effort in the Congress had been made possible by the strongest bi-partisan effort. On our Senate Space Committee, one of the ablest members is the gracious lady from Maine, Senator Margaret Chase Smith. When the new Congress opens, she will be the ranking Republican member on our committee. And I know that this program is near and dear to her heart, and I congratulate her on the tremendous contribution that she and her colleagues in the committee have made to it.

Mr. Administrator, it is a great pleasure to me to present the distinguished lady from Maine, Senator Margaret Chase Smith.

SENATOR SMITH: Thank you very much, Mr. Chairman, my Chairman of the Senate Space Committee.

I am pleased to have the opportunity to be on hand as this great step forward in the advancement of scientific knowledge is taking place.

Scientific achievements in space are less dramatic than our efforts in manned space flight. But the events taking place today, in the vicinity of Venus, are a significant demonstration of the fact, but they are no less important.

What is being learned will not only add substantially to our understanding of the universe, but the contribution of Mariner 2, to our knowledge of the space environment will help in the years ahead to ensure the success and the safety of the astronauts who journey outward to explore the moon and the planets beyond.

Perhaps the firmest evidence of our national determination to lead the world in peace exploration and the utilization of space is the strong bi-partisan backing which has been given in our space program by the Congress, by President Eisenhower, under whose leadership NASA was created, and President Kennedy, who has given it continued support.

This is an important demonstration of the fact that partisanship can end with the closing of the polls, where important national objectives are concerned.

In carrying out our national efforts in space we have faced some difficult decisions. They will become even more difficult in the future, for, as our capability in space increases, so does the demand which our space endeavors make on our national resources.

The events which have occurred in the past 24 hours demonstrate how important it is that we maintain a broad-based program of space research. In tailoring our space program to fit the available resources, we must not succumb to the temptation to concentrate on any single goal at the expense of important scientific and applications programs such as Mariner.

It is a privilege, Mr. Administrator, to be here today, and I want to congratulate all those who have contributed to the success of the Mariner program and made possible this first important "first" in space for the United States.

WEBB: Thank you, Senator. It is wonderful to have you here when we are moving toward Venus. We are going to get pretty close to it.

Let's say, also, while we are waiting to hear from Mariner, Dr. Seamans will continue with out little program.

SEAMANS: We have had wonderful support from the Senate and also from the House of Representatives. Congressman Karth would like to say a few words. We are glad to hear from him.

CONGRESSMAN KARTH: Dr. Seamans, I merely want to extend the congratulations of Chairman Miller, of California, who is Chairman of the House Science and Astronautics Committee, and, for that matter, the entire Committee in the House of Representatives to not only you but Administrator Webb and such real outstanding scientific minds who have really made this thing a success -- Dr. Pickering, Dr. Homer Newell, Dr. Dryden, and Mr. Cortright.

And may I also extend congratulations to American industry and the technicians who have played a major part in this very outstanding achievement, a real American "first".

And last, but obviously not least, let me congratulate the American taxpayer for understanding the reasons why it is important for our government to go forward with a program such as this.

Thank you.

SEAMANS: Now we will move on to that part of the program where we will find out more about the status of the Mariner. Dr. Homer Newell will be the first officer to lead off on some of the specific aspects of the Mariner 2 program.

Dr. Newell.

NEWELL: Thank you.

Senator Kerr, Senator Smith, Congressman Karth, and my colleagues, ladies and gentlemen: Mariner program plans were first formulated early in 1960, including early use of Centaur. The spacecraft development effort was aimed at test flights in 1962 and 1963, and operational fly-by missions to Venus and Mars in 1964.

In mid-1961 the program was reoriented to include operational fly-by missions to Venus in 1962, using the Atlas Agena to launch a 450-pound spacecraft, considerably lighter than the Centaur version. This was the beginning of the program that led to the launch and flight of Mariner 2.

The revised program involved a tight schedule of 10 months from start to launch, and was possible only because Ranger and the heavier Mariner developments and hardware were already available.

Mission objectives were chosen to be compatible with the available technology. The objective was to launch two space vehicles in July and August of 1962, with the intention of:

Placing a scientific instrument package in the vicinity of the planet;
Transmitting data from the instruments back to Earth; and
Gathering scientific information during the trip to the planet.

After feasibility studies showed these objectives could be met and that the instrument package could weigh about 40 pounds, the instruments themselves were chosen.

Although Venus comes closer to Earth than any other planet and is the brightest object in the sky except for the Sun and Moon, it has been a "mystery" planet ever since the invention of the telescope. A dense cloud cover precludes any observation of its surface. Until recently, because of the heavy cloud cover, it was thought that Venus was a planet in an early stage of evolution -- perhaps similar to the Earth some 200 to 300 million years ago -- with thick green forests and a moist, warm atmosphere.

Gradually, this view has changed as additional instruments have been brought to bear -- radiometers to measure temperature, spectrometers to study the chemistry of the atmosphere, photometers to investigate the nature of the particles in the clouds and, most recently, radar to determine surface roughness and the rotation rate as well as the distance to Venus.

At present, it appears that there are at least two layers of clouds, an upper layer which is somewhat broken, and a more solid layer close to the surface.

The surface temperature is a surprisingly high 600°F, very likely because of a strong "greenhouse effect" associated with the large amount of carbon dioxide known to be in the atmosphere. The rotation rate appears to be considerably slower than that of Earth. Although much has been learned, many questions about these and even controversial items are yet to be resolved.

Generally speaking, ground-based observations have two drawbacks: First, the atmosphere of the Earth makes certain observations difficult and others impossible; and, second, because of the planet's remoteness, Venus appears to many instruments as just a single spot, so that the distribution of the measured quantities over the surface can not be determined.

Mariner experiments were chosen with these current mysteries in mind, and are designed to gain information in areas which can not be investigated from the Earth. The payload also carries instruments for obtaining interplanetary data during the 109-day trip from Earth to Venus.

The interplanetary instruments have now been in operation for 99 days. These instruments were turned on during the third day of flight, and were off for an eight-day period while the effect of a short circuit in one of the solar panels was being examined. During the time that the instruments have been in operation, approximately 5 million scientific data points have been obtained. The instruments which have been in operation are: A three-axis magnetometer, an energetic particles package, a solar plasma probe, and a cosmic dust detector. These experiments and the experimenters associated with them are indicated on the chart.

A report on these instruments was presented in a press conference held here in Washington on October 10, 1962. Without going into detail, the significant results include the following:

The plasma probe revealed a steady "solar wind" of about 250 to 450 miles per second.

The magnetometer showed that space contains fields of at least a few gamma and that there are fluctuations by factors of as much as five to ten. Typical transverse fields lie between five and ten gamma and incline toward the plane of the ecliptic.

For the interest of the audience, a gamma is a special unit about one one-hundred thousandth of the intensity of the Earth's field at the equator.

The energetic particles instruments indicated an intensity similar to that shown on previous missions.

The cosmic dust detector indicated that the meteoritic particles in space are less numerous than near Earth by a factor of 10,000.

These data will not be completely evaluated for some time. Reports will be issued in the scientific literature as the information becomes available.

Turning now to the measurements that are being made today, relative to Venus, the spacecraft will be approaching from the dark side along a direction pointing slightly to the right of and below the Sun. The radiometers were activated as the spacecraft came into the vicinity of the planet.

Perhaps the most interesting and puzzling of the current scientific questions about Venus is the high apparent surface temperature. Since 600° F is approximately the melting point of lead, it is clear that that is important to future attempts at a landing on the planet, as well as being of scientific interest. The microwave radiometer may answer the question as to whether this indicated temperature comes from the surface or, as has been suggested, from a very strong ionosphere. As indicated in the chart, the 19 mm channel should "see" the surface. In its scan across the planet, and as it approaches the edge, the radiometer will look through an increasingly thicker atmosphere. Thus, if as it approaches the edge, the temperature decreases, a limb darkening will be observed, showing that the temperatures being measured definitely come from the surface. If, on the other hand, the temperature increases as the scan just sweeps off the planet, this will show that the source of the temperature is high in the atmosphere, and possibly of ionospheric origin.

The 13.5 mm channel of the radiometer is located at a water vapor absorption line, and a comparison of the temperature measured by this channel with that of the 19 mm channel may tell of the presence of water on Venus.

The infrared radiometer is a companion instrument to the microwave radiometer. Successful measurements from the two instruments will permit both surface and atmospheric temperature distributions to be obtained. The infrared radiometer is a dual channel instrument: one channel in the eight to nine micron region should see through the atmosphere -- but not the clouds; the other, in the 10 to 10.8 micron region, will see carbon dioxide. Comparison of these two channels should provide a picture of the fine detail in the cloud cover.

Both instruments -- the infrared and the microwave radiometers -- are mounted on a common support which swivels 120° at a 0.1° per second rate. During the period that they are viewing the planet, they see an area approximately .02 of the surface and so will provide a map of the temperature distribution.

The instruments that have been in operation during the trip are also important in the vicinity of the planet. The fields and particle packages are of particular importance. The field of the planet has never been measured -- we are talking about the magnetic field here -- and the existence of radiation belts is a complete unknown. Both measurements also have implications in other areas. For example, magnetic fields, rotation rate, and internal structure of the planet are closely related phenomena. Fields as small as one-tenth that of Earth should be detected by the magnetometer.

Finally, there are numerous scientific aspects to the tracking data obtained by tracking the spacecraft during its flight. The trajectory has been measured during tracking exercises that were performed weekly during the entire trip. The trajectory will also be measured as Mariner approaches and is affected by the gravitational field of Venus. Mariner will speed up during approach, and will slow down as it leaves the planet. The curvature of its path will also be affected. These measurements should assist in improving estimates of the astronomical unit -- that is, the distance from the Earth to the Sun, the mass of the Earth, and the mass of Venus.

As we have been talking, the spacecraft has been approaching Venus. By 1:55 this afternoon, Mariner had moved into position for the first radiometer view; the distance from Venus at the time was 25,300 miles. At 2:17 p.m., the spacecraft was opposite the terminator, that is, the dividing line between the sunlit and the dark sides of the planet. By 2:37, at a distance of 21,700 miles, the radiometer "look area" will move off the disk and this experiment will be completed. At 3:01, Mariner will reach its closest approach -- 21,100 miles from the surface. At this time, Mariner will be traveling 15,000 mph relative to Venus, and 88,400 mph relative to the Sun. Distance from Earth will be 36,000,000 miles.

We have approached the time for receiving the signal from Mariner, so I will turn to Dr. Pickering for this.

SEAMANS: As you all know, the Jet Propulsion Laboratory is intimately tied in with the NASA program. It is operated by the California Institute of Technology, on contract to our organization.

Dr. Pickering, the Director of the Laboratory, is here with us today. I don't believe he has been quite holding his breath for the last 109 days, but he is coming pretty close to it. I am sure it is a great relief to him that the data is now coming in from the planet.

Bill?

PICKERING: Thank you. Perhaps, to begin with, we might ask Pasadena if they would turn on the signal which they are now receiving from Mariner, 36,000,000 miles from the Earth, a few thousand miles from Venus.

Pasadena, will you turn on the signal, please?

(The signal from the spacecraft Mariner 2 was heard via JPL, Pasadena, California.)

The shifting of the tone from time to time is when we switch from one instrument to another. This signal is placed into appropriate equipment at the Laboratory, and eventually the readings of the instruments are presented.

Mariner has been sending a steady signal like this since we left on August 27. Thank you very much.

I might point out that the signal is being received loud and clear from Mariner to Goldstone to Pasadena to Washington.

QUESTION: Dr. Pickering, how many tones are in there, do you know?

PICKERING: No. Quite a lot of them.

Let me comment again on the signal. This is the signal as it is received. The switching from one tone to another represents the switching from one measurement to another. The measurement is indicated then by the switching and by the frequency of the tone.

I would like to outline for you the events which occurred in the Mariner mission.

On August 27th we launched. The launching, incidentally, was restricted to about a 1-1/2-hour window, during which the Earth would be in the right position for the launching from Cape Canaveral. We launched near the middle of the window, actually about 70 minutes from the beginning of the window.

After the Atlas had burned, then the Agena was turned on for the first burn, and the Agena plus spacecraft brought up to satellite speed. We stayed at satellite speed for 16 minutes in a parking orbit, and then the Agena was turned on again to accelerate to the necessary speed to leave the earth: 11.4 kilometers per second. This occurred over the South Atlantic in about latitude 15 South.

Two and a half minutes later, separation between the Agena and Mariner occurred. The Agena rocket was turned around and a small impulse given to it so that it would get away from the vicinity of the spacecraft.

About eighteen minutes after injection the solar panels were opened. Thirty-four minutes after injection the Sun was acquired. This was the first action of the spacecraft, so that we are now pointing at the Sun and electrical energy is being generated by the solar panels to operate the equipment. The spacecraft is in a slow roll, about once in 20 minutes. During this time various engineering and scientific measurements were made.

The spacecraft science was turned on, on August 29th, two days after launch. This slow roll at this time was a very convenient way of calibrating the magnetometer aboard the spacecraft.

For about the first week the vehicle was tracked, and it was determined that the vehicle had missed the planet Venus by about 223,000 miles, about roughly the distance from the Earth to the Moon. This was well within the expected accuracy. We then proceeded to calculate an appropriate midcourse correction to bring the miss down to the expected magnitude.

On September 3rd the spacecraft acquired the Earth, that is to say, it stopped rolling and pointed its high-gain antenna at the Earth. From then on it was kept locked onto the Earth and locked onto the Sun.

September 4th was the midcourse correction. In order to do this we had to ask the spacecraft to roll through about 9 degrees, to turn over through about 140 degrees, to turn on its rocket engine, and give itself a speed of about 90 feet a second. Then to turn off the engine, to turn back and find the Sun, and roll around and find the Earth. This whole process worked very well. For a period of about four hours, then, the maneuver was being carried out.

This maneuver, then, was to select a target point much closer to Venus. On this chart I can indicate the target problem.

We wanted to arrange it so that we would go by Venus when we could observe the encounter from out tracking station at Goldstone, California. We also wanted it to be close enough to the planet so that the planet subtended an angle of at least 10 degrees. That put the outer distance at about 40,000 miles from the planet.

We wanted it to be not so close to the planet that it subtended an angle of more than 45 degrees. That put an inner limit of about 9,000 miles from the surface. We also wanted it so that it would go by near the equator of the planet.

Our aiming point is indicated on this chart. Our first estimate rather was that we had come about 9,000 miles from the surface near the inner edge of our bulls eye. Actually it turns out that we were out, as indicated there, about 20,000 miles from the planet. The final estimate of this point was made by tracking the spacecraft for some weeks after the midcourse correction.

Parenthetically, I might note that the trajectory, as we observe it today, now that it is getting near the planet, seems to be very close to this predicted 21,000-mile miss.

On September 8th we noticed a curious event on the spacecraft. It received some sort of a disturbance which momentarily knocked it out of its attitude control. This lasted only a minute or so, and then came back tracking the Earth and the Sun. We don't know whether this was actually an encounter with a micrometeorite or whether it was an electrical disturbance. In either case, it was a relatively minor disturbance.

During this whole period, then, the spacecraft is being kept pointed specifically at the Sun and at the Earth, so that it is stabilized in space.

On September 29th -- it says September 28th here; I think actually it was September 29th -- we had another problem in the stability of our spacecraft. The Earth sensor had been indicating that the signals it was receiving by reflected light from the Earth were weaker than we had expected. We believe this to be some sort of an instrumental problem. But the signals got progressively weaker until, on September 29th, we actually lost the roll control of the spacecraft, and again it started to roll. It only rolled momentarily for a few minutes, and then it came back again onto the Earth, and this time, for reasons which are not very clear to us even yet, the Earth sensor proceeded to give the correct calculated value of the signal. So that we believe that what must have happened was that this device, which is a telescope and photocell, in some way was locked onto some sort of a ghost image inside of the telescope, and that after the disturbance it came back on where it should have been all along, and the Earth sensor then proceeded to give its correct signal.

Since then it has worked correctly, except that as we have been approaching the planet the temperatures have been rising because we have been getting closer to the Sun, and there has been some loss in sensitivity of the Earth sensor within the last few days.

The next event which disturbed us, on October 31st, we had an electrical short develop in one of the solar panels. Shortly after this had been observed we turned off the scientific experiments and just left on the engineering measurements, and wanted to analyze the problem to see what was happening.

After about a week the short cleared itself. We turned the science back on, and everything was normal for about another week, and then the short developed again, and it is still shorted.

The loss in power which occurred because of this was not sufficient to put us in serious trouble. We had sufficient redundancy in the system so that the power system has operated properly and the complete vehicle has operated properly in spite of this electrical short.

On November 25th we were about 22.5 million miles from the Earth. At this time we claimed a communication record. It is interesting to note that the previous communication to this distance was done by the U.S. probe Pioneer V, which was launched in the spring of 1960. Signals were lost on Pioneer V at about that distance. And then, today, of course, we are now in the fly-by mode.

I would merely comment that the distance, as Dr. Newell said, the distance from the planet was about 24,600 miles at two o'clock, and it is supposed to be about 21,100 miles at three o'clock. The information which I have from Pasadena is that the spacecraft seems to be following very closely along the predicted approach to Venus.

SEAMANS: Bill, I would like to personally congratulate you and all the members of your very fine team at JPL.

PICKERING: Thank you very much.

SEAMANS: Next on the agenda we have Mr. Cortright. Mr. Cortright was in charge of our lunar and planetary program here in Headquarters before becoming the Deputy Director for the total space science effort under Dr. Newell.

Mr. Cortright.

CORTRIGHT: Thank you, Dr. Seamans.

Ladies and Gentlemen: I have the great pleasure of saying a few more words about the team that did the job.

During the last few weeks of the Mariner mission I have been repeatedly asked by you and your colleages: who was responsible for this project. Today I am taking the opportunity of answering this question.

The answer is, simply: no one person, as you might suppose. Mariner 2 was a product of a great team effort. This is not merely a trite but true-type answer. Without the well-integrated government, university, and industrial teams which we are now employing, the exploration of space might never be successfully accomplished.

The basic elements of the Mariner 2 team are illustrated in a chart which I have here. You can't read it, but you will have an opportunity to look at it later. Unfortunately the chart can not begin to do justice to the number of people who played a part in this project.

Responsibility for the overall management of the national program for planetary exploration, of which Mariner 2 is a part, has resided within NASA Headquarters, and in particular within the Office of Space Sciences.

Execution of the Mariner 2 project has been the responsibility of the Jet Propulsion Laboratory, of the California Institute of Technology.

As Project Manager, JPL has been responsible for overall technical direction and coordination of the three systems managers: for launch vehicles, spacecraft, and tracking and data acquisition, these three main groups of people shown on the chart.

JPL designed the Mariner spacecraft, fabricated or procured components for it, and assembled and checked out the flight hardware. In addition, JPL has mothered the Mariner through 109 days that would make the "Perils of Pauline" look like a nursery story.

As the spacecraft systems manager, JPL was supported by 34 subcontractors and over 1,000 suppliers of parts. All told, approximately 1,200 man-years, and $25 million went into the development and fabrication of the Mariners 1 and 2.

As systems manager of the tracking and data acquisition system, JPL was assisted by the Bendix Radio Corporation at the Goldstone (California) antenna site; by the South African Council for Scientific Research, at Johannesburg, South African Antenna site; and by the Australian Department of Supply at the Woomera, Australia, site.

During its flight the Mariner has virtually monopolized these facilities, requiring an investment of about 60 man-years and $2.5 million.

The launch vehicle systems manager has been the NASA George C. Marshall Space Flight Center in Huntsville, Alabama. This Center contracted with the United States Air Force Space Systems Division for modified versions of the Air Force-developed Atlas Agena-B launch vehicle.

The prime Air Force contractors in delivering and launching these rockets were the Lockheed Missile Systems Company, for the Agena-B, with upper stage; General Dynamics Astronautics for the Atlas itself; Rocketdyne, an associate contractor on the Atlas, for the Atlas engines; General Electric and Burroughs, associate contractors for the Atlas guidance, and the Space Technology Laboratories, for the guidance equations.

And I might pause at this time to inject an interesting note, that the editing equations, which were much discussed after the failure of Mariner 1 were subsequently very well corrected and were called into play during the Mariner 2 launch.

The NASA Launch Operations Center teams with the Air Force and its contractors in the launch preparations and launch. This group succeeded in launching Mariner 2 in little more than one month after the unsuccessful attempt to launch the first Mariner, thereby setting some sort of a record for turnaround time on the pad at AMR. It is a credit to all people who made that possible.

The numbers of subcontractors and suppliers for the Atlas Agena launch vehicle was even greater than for the spaceraft. Some 1,100 man-years, and $19.5 million, were expended on the launch vehicle phase of this effort.

Even this over-simplified picture begins to convey, I think, the national and even international scope of the team effort involved. Although key individuals provided the glue that held this team together, each of the thousands of participants played a necessary and perhaps even crucial role. I find it now a severe temptation to single out key individuals at a time like this, starting with the JPL Planetary Program Manager, Bob Parks, and the Mariner Project Manager, Jack James, who, at this moment, are busily masterminding the Venus fly-by.

Proceeding down the list of important individual contributors, I would run out of time before I would run out of names. Rather, let me close with this thought:

Mariner, and its launch vehicle, contain thousands of parts that had to work, and did. Thousands of people had a hand in this. Whether they managed the project, signed a contract, planned an experiment, designed a circuit, double checked a component, tightened a nut, or typed a letter, they can be justly proud of their role in making this little bit of history come true.

Thank you.

WEBB: And the science writers who wrote the stories that informed the Free World all about it.

SEAMANS: When Mr. Cortright talked about the "Perils of Pauline," I can remember the day not so long ago when he came into my office and indicated that the temperature of the Mariner 2 was rising more rapidly that it had been anticipated, and that there was a possibility that the temperature would reach the point at about the day Mariner 2 was passing Venus where the batteries would actually explode.

Ed, I am glad that they did not explode; at least not until after the passage.

In closing the formal part of this press conference, I would like to take note of the presence of Mr. Maxwell Hunter, who is sitting in the front row, who is here representing Dr. Edward Welch, Secretary of the Space Council.

We will now have a 9-minute recess, at which time we will hear the Mariner 2 again, and then we will have the question and answer period.

(Recess)

MITTAUER: Ladies and gentlemen: At 3:00 o'clock there will be the signal of Mariner coming again from the Jet Propulsion Laboratory. Following that, Dr. Pickering will be talking to JPL, to Mr. J. N. James, who is Mariner Project Manager for the Jet Propulsion Laboratory, for the latest information.

PICKERING: Ladies and gentlemen, we will have a signal from Venus turned on again. I would like to make the point, incidentally, that this is not a canned recording of the signal. This is as it is actually being received in Pasadena, then sent over the wire here to this room. So, Pasadena, can you turn on the signal again, please?

(The signal from the spacecraft Mariner 2 was heard via JPL, Pasadena, California.)

PICKERING: At this time the spacecraft is at its closest distance to Venus, about 21,000 miles from the surface.

I would like to comment, incidentally, that the spacecraft transferred from the cruise mode to the encounter mode this morning at about 8:45, out time. This is a change in the measurements being made by the spacecraft. During the cruise mode we are making engineering measurements of the performance of the spacecraft, and we are recording appropriate scientific measurements for the interplanetary environment.

During this cruise mode we turn off the engineering measurements and turn on the additional radiometer measurements as we go by the planet.

The turn-on to the encounter mode was programmed to take place automatically about midnight last night. It did not take place automatically, and so a signal was sent from Goldstone this morning, and the turn-on was effected.

Just as a matter of interest, that signal took about three minutes to go each way. So that after the command was given, it was almost 6.5 minutes before the spacecraft came back and said, "Okay, I heard you, I turned it on." And it was turned on then about a quarter to nine this morning.

I think we can have the tone off now. I would like to ask Jack James, in Pasadena: Jack are you on the line?

JAMES: Yes, Dr. Pickering. Can you hear me?

PICKERING: Yes, I can hear you. Maybe you should talk up a little so we can get it against the room noise out here.

JAMES: Very well. How is this?

PICKERING: That is fine.

Jack, I would like to ask you how things are going out there; how are you feeling out there in Pasadena?

JAMES: The spacecraft is working very well.

PICKERING: It is working very well. That is good.

Would you tell me first, what sort of Doppler data you have been getting?

Let me explain to the audience, that as the spacecraft approaches the planet Venus, the gravitational field of Venus begins to attract it, and so it speeds up. The first faint evidence of this attraction by the planet Venus was measured as early as last Tuesday. And since that time we have been able to detect the increase in speed as it comes closer to the planet, and within the last hour or two this increase in speed should have been very noticeable.

Jack, what kind of doppler data did you get?

JAMES: We are getting excellent doppler data, Dr. Pickering. As you know, we just made our closest approach to the planet a minute or so ago. The velocity plots are going right along the predicted curves. In fact, they are following the predicted curves something better than three miles per hour accuracy.

PICKERING: That is pretty good, Jack, three miles per hour out of a speed of 40,000 miles per hour with respect to the Earth, 88,000 miles per hour as measured from the Sun. That is very good accuracy, Jack.

What about the scientific measurements? I know it is very early to say anything about the scientific measurements, but do you feel that the instruments have been working satisfactorily?

JAMES: Yes, sir. Incidentally, this is the best news. There is an unqualified report to make. We have definitely received significant data from both the microwave and the infrared radiometers. These instruments have both scanned the planet and we have received significant data from the planet.

PICKERING: That is very good news indeed, Jack. That, I think, is very significant. This is the news that I think we have been hoping for, that as we went by the planet, the spacecraft would indeed, with its radiometers, be able to scan across the surface of the planet and make measurements.

Of course, it will be some time before we are able to interpret these measurements, but -- did you say that all four of the radiometers, two infrared and two millimeter waves, all four radiometers gave data?

JAMES: Yes, sir, that is correct.

PICKERING: That is very good, indeed. This will be most interesting scientific data.

At this time we are just past the closest approach, and I assume we have passed the scanning of the planet, have we not? We are no longer scanning?

JAMES: Yes, sir, that is right.

PICKERING: Then I suppose soon we snould turn back into the cruise mode and make some engineering checks on what has happened to the spacecraft during its passage by the planet. When will you turn back to the cruise mode, Jack?

JAMES: The planned time for transmission of this command to revert to the cruise mode will be approximately 3:40, you time.

PICKERING: 3:40 our time we will be back to cruise mode?

JAMES: Roger.

PICKERING: That is very fine.

Jack, I am very pleased indeed to get this news. In addition to these radiometer measurements of the planet, of course, we are also looking to see planet-associated effects occurring on some of the other instruments, such as magnetometers, radiation measurements cosmic dust measurements; all of these instruments may give some indication as we go by the planet.

I don't suppose you have had a chance to look at the magnetometer yet, have you, Jack?

JAMES: Well, actually all the instruments have been examined, and there is every evidence that they are working properly. We have not had a chance to evaluate the data to actually see whether we have had any changes.

PICKERING: Okay. Thank you very much, Jack. I am very pleased indeed, and certainly give my personal congratulations to everybody out there for this magnificent achievement.

JAMES: Thank you, sir.

PICKERING: Now I think we can go into a question and answer session.

SEAMANS: Before we start the questions, Dick, I wonder if Dr. Newell shouldn't introduce the new faces we have here at the table.

NEWELL: I would like to introduce to you the man who has had charge of the Mariner program in the Office of Lunar and Planetary Programs, the Mariner Program Chief, Fred Kochendorfer.

And the Director of the Office of Lunar and Planetary Programs, Oran Nicks, who has cognizance over all of our lunar and planetary programs.

MITTAUER: We will now entertain questions. May I explain briefly that we have the press listening to this conference at Pasadena, and they are forwarding questions. Every so often I will intersperse a question from the press at Pasadena.

Will you identify yourself by name and affiliation, so they will know.

QUESTION: Can you now give us a range of a few miles as to how close this has passed?

PICKERING: No. It will be a little while before we calculate just what the miss-distance actually is. But since we have had a solid doppler track during the encounter, this means that we should be able to make a very precise calculation of the miss-distance. The report that Jack James gave us that said that the doppler track looked as though it was very close to the predicted one probably means a miss-distance will come out very close also.

QUESTION: Dr. Pickering, does this mean that actual contact has been made with the surface of the planet?

PICKERING: Yes, it does.

QUESTION: You have a Venus radar experiment going on concurrently with this thing. I wish you would tell us a little about that, and how it ties in with this Mariner mission.

PICKERING: Yes, indeed. Yes, we are conducting a Venus radar experiment also out at Goldstone, in which we are sending radar signals to the planet Venus, and receiving the echoes from the planet.

This was first done a year and a half ago when Venus was close to the Earth, relatively close to the Earth, and signals were received at that time which enabled us to measure the distance to Venus very precisely.

This measurement resulted in the calculation of what is known as the astronomical unit which, if you like, is a sort of a scale factor for the solar system. It was very important to us because of the fact that when we were aiming at the planet Venus, of course we had to know where to aim, and how far to travel. And the difference between the radar measurement of this distance and the measurement made by the astronomers on the basis of astronomical calculations would have been about 50,000 miles at the planet Venus.

Perhaps it is a little early to say this, but I think, nevertheless, that the fact that our encounter mode seems to be very close to the predicted one is an indication that the radar measurements of this distance which were made a year and a half ago were not only very important but necessary if we were to come this close.

The measurements which we are making this year are a refinement of the measurements which were made a year and a half ago, and we are attempting to get information on the rotation of the planet Venus and perhaps some information about the nature of the surface by looking at these reflected signals.

Incidentally, I was interested and amused to see a memorandum go around the laboratory a couple of days ago which said, "We are hereby requesting radio silence on Venus at three o'clock this afternoon" so that the radar measurements would not get themselves confused.

QUESTION: Can anything be said at this time about the physical condition of the spacecraft? Anything about the temperatures encountered?

PICKERING: The temperatures were being measured up until we switched into this encounter mode. The temperatures which were measured were somewhat higher than we had before we left the Earth. They ranged in the general area of 140° or 150° F.

This was obviously not so high as to be disastrous. It was a little high for some of the instruments, and, as Bob Seamans mentioned earlier, at one time we were concerned that a battery aboard might explode, just because of the temperature. The battery obviously has not exploded. In other words, the temperature has caused us a little trouble, but no serious trouble.

MITTAUER: May I interrupt, gentlemen? We are going to have to repeat the questions for the people in California. They can not hear the question.

QUESTION: Dr. Pickering, how long before data can be analyzed which may or may not indicate some form of living organism on Venus?

PICKERING: It will be several days, or maybe weeks, before we are really able to analyze the data which we have received.

Of course, if the current best theory that the surface of Venus is at a temperature of 600° F, if that theory is correct, I don't think we can expect any living organisms, at least of the type which we know.

QUESTION: Could you repeat the answer to that question, please?

PICKERING: The question concerned when would we be able to analyze our data to know whether or not we had any evidence for life on Venus.

I will answer the question in two ways: One, that the time required to analyze the data will be certainly days, and probably weeks.

The question as to whether or not the data will say whether there is life on Venus or not, the data is not really expected to answer that question. However, if the data confirms the present theory that the temperature of the surface of Venus is around 600° F, then I must surely conclude that life as we know it could not exist on the surface of Venus.

QUESTION: Is there anything in the data you will get that will enable you to deduce the presence of oxygen in the atmosphere of Venus?

PICKERING: The data will give us indications of carbon dioxide or of water vapor, but not directly of oxygen.

QUESTION: Dr. Pickering, some of this other data like magnetic fields and cosmic dust ought to be reducible fairly quickly. Can we have that this evening, do you think?

PICKERING: The question is whether you can have any data this evening. I will have to ask the boys out in Pasadena. But I don't think there is going to be much data available this evening. I think they probably have other plans.

(Laughter.)

QUESTION: Can you tell me, please, whether you plan to turn off the radio equipment on Mariner, and when this will be done. Whether you plan to keep it broadcasting for a longer period of time?

PICKERING: The question is whether we intend to turn the radio equipment on Mariner off.

We will certainly tack it for some time beyond the planet, as far in fact as we can. We would like to not only continue the measurements, but also to continue the experiment of the performance of the spacecraft.

The thing which is probably going to happen is that the spacecraft's Earth sensor will lose control after a period of perhaps days, perhaps weeks. At that time the spacecraft will begin to roll, and from then on very little data will be receivable.

Of course, the distance which the spacecraft gets from the Earth goes up tremendously as it goes around the Sun. As a matter of fact, I think we have a chart here which showed the orbit as it went on around the Sun. It will have a period in the general order of about four hundred days.

It will actually go outside the Earth's orbit and will not come close to the Earth for -- we have not carried this out very far. We have carried it once around. The closest it gets to the Earth, I think, is about forty million miles.

QUESTION: Don't you have to eventually, shut off the radios anyway for reasons of not cluttering up space?

PICKERING: I think the signals from this particular probe are so weak that we are not really in much danger of cluttering up the spectrum.

QUESTION: Dr. Pickering, I wonder if you could ask the people out at Pasadena whether, from a quick glance at the data coming in, they could give us any indication of the temperatures being recorded at the surface?

PICKERING: I don't think I want to ask them that, because I am sure they can't really give us that yet. This data has to be reduced. It depends on distances which have to be fed in, and the geometry of the orbit as it goes by, and things of this sort. I think that it is certainly too early to expect any such reading as that.

I think the reading which would come out most quickly will be a magnetometer reading. That will be the first sort of thing which we might expect, as to whether or not there is any magnetic field, any detectable magnetic field.

MITTAUER: May we interrupt Washington for a couple of questions from the West Coast?

First, how far beyond Venus does it appear likely that communications from Mariner will be useful?

PICKERING: The question is how far we can go beyond Venus.

Assuming that the spacecraft continued to operate, and be stable, so that the high-gain antenna is pointed at Earth, we could probably go out to a distance of about twice the present distance.

MITTAUER: I have one more.

Regarding the signals just heard -- the ones at three o'clock from Mariner -- was the switching of data channels deliberately programmed to sound melodic?

PICKERING: No.

QUESTION: Dr. Pickering, if we can get to Venus -- I don't know how to put it. If we can get to Venus, why can't we get to the Moon?

PICKERING: We can. We will.

QUESTION: Any hot surface -- or cold surface, for that matter -- is radiating energy at a number of different wavelengths, including wavelengths in the infrared and in the millimeter part of the spectrum. So all we really do is put a sensitive receiver at the focus of a little telescope of some sort, and we just read the temperature then of that little receiver. This is the same sort of thing that astronomers do on the Earth with infrared detectors at the focus of their telescopes, or that the radio astronomers do when they look for radio noise from the Sun, say. They observe signals in the millimeter and centimeter part of the spectrum coming from the Sun, just because of the thermal radiation. This is in effect what they are measuring.

QUESTION: Excuse me, on twice the distance beyond Venus, do you mean 72 million miles essentially?

PICKERING: Approximately, yes.

In other words -- let me put it this way: the present signal strength that is being received at our stations is about -150 dbm -- 150 decibels below a milliwatt. The limiting sensitivity of the stations is not really known but it is certainly at least as low as 156, or maybe even lower than that. And therefore we should be able to get measurements at least twice as far.

QUESTION: Will any of the data from Mariner help resolve the Soviet-U.S. problem on rotation of the planet; and what is the best guess of the rotation now?

PICKERING: Let me make a parenthetical comment here, that at the last opportunity when Venus was in conjunction with the Earth, and Venus radar experiments were performed, you remember that in this country MIT and ourselves each conducted radar experiments. In England, Sir Bernard Lovell conducted one. In Russia, Kotelnikov and some of his people conducted an experiment. The results of this experiment were in reasonably good agreement, after an initial disagreement, were in reasonably good agreement as far as the range to Venus was concerned.

The American data and the Russian data were in disagreement as to whether the data showed any evidence for a rotation of the planet Venus. The Russians said that their data indicated a rotation with a period of about 10 Earth days. The American data showed a rotation rate very much lower, and strongly suggested that Venus kept the same face always pointed toward the Sun.

The data which we are receiving at Goldstone with our Venus radar experiment this year continues to be suggestive of a very slow rotation rate of the planet Venus.

It may turn out that the radiometer measurements on the dark and light side of Venus may give some clues from temperature distributions as to whether there is such a situation where one side is always facing the Sun. I don't know. It is a very interesting possibility.

QUESTION: Is there anything in your sensors which might pick up temperature levels off the surface of Venus, up in the atmosphere somewhere which would indicate levels conducive to some life form?

PICKERING: Yes. In effect we will get measurements from cloud layers, depending on the nature of the clouds and the nature of the gases present. In other words, by measuring carbon dioxide and water vapor absorptions, one will get clues as to the temperature distribution above the surface. Much this same sort of thing has been done from the Earth and some of the measurements of the planet Venus. Analysis of the sorts of temperatures to be encountered at the cloud banks indicate much more reasonable temperatures.

QUESTION: Will you get a gradation, a better gradation than you have been able to get before at various levels?

PICKERING: Let's say we will get more of a spatial distribution, rather than necessarily a finer total distribution. In other words, the data which you can get from the Earth can be conducted with more elaborate instruments, but can not resolve differences across the face of the planet. And also can not make measurements in which the atmosphere of the Earth interferes with the measurements.

What we are getting with these experiments, then, are the first direct measurements near the planet which will give us a sweep across the surface.

Obviously the instruments aboard this particular spacecraft are not nearly as elaborate as one would like to have in future experiments. And I hope that we will have future experiments with a wider variety of instruments to give us more of the kind of data you are looking for now.

QUESTION. Can you tell us what your plans are for Mariner in 1963 and the kinds of things we will be looking for?

PICKERING: Mariner in 1963? No. The next opportunity for Venus is roughly a year and a half from now, so it will occur in the early part of 1964, and we do intend to have an additional experiment of the planet Venus at that time, and then the planet Mars, when we will have an opportunity towards the end of 1964.

MITTAUER: I would like to interrupt. There are a couple more questions from the West Coast, if I may.

QUESTION: JPL scientists have said they should have a rough indication within minutes after encounter as to whether Venus is as hot as it is supposed to be. Do you have any results?

PICKERING: The answer is, somebody said we would get an indication within minutes. That was a little bit optimistic.

QUESTION: Some 8.5 million measurements were taken. Has this proved of value to the Department of Defense in calculating its distance estimates? If so, how?

PICKERING: I don't really understand the question.

As far as the measurements, which have been made en route to Venus, these are primarily scientific measurements of the interplanetary phenomena which are occurring out in space between the planets. As far as distance measurements in the solar system are concerned, the radar measurement, combined with the data from this pass near Venus, will indeed give us very much more refined information about the whole geometry of the solar system.

MITTAUER: I have one more from the West Coast.

QUESTION: Can you predict the distance from Earth that radar will nolonger be able to track the spacecraft?

PICKERING: I assume this question relates to the one we had before: namely, we are not really tracking by radar but we are looking for signals. We could hear signals if the spacecraft continued to operate for a distance of at least twice the present distance.

QUESTION: Could you tell us a little bit more about this astronomical unit? You said, as I recall, that the radar estimates were a thousand miles different from the astronomical. Were they longer or shorter, and what is the plus or minus? How close are they?

PICKERING: The astronomical measurements are made, of course, by observations with telescopes from the Earth, and therefore involve essentially measurements of angles from the Earth, and from those calculations of the path of the various planetary bodies and of the disturbances in their path. The radar measurements are of direct range measurement or velocity measurement and very much the classical radar method.

The two methods give measurements which differ by several times the estimated probable errors in each method. The radar measurements give a larger distance than the -- yes, I think it is larger -- than the astronomical one. For a journey, such as this journey to Venus, the difference would have been of the order of 50,000 miles. The accuracy which we estimate the radar measurements to have is something like 500 miles. The estimate which the astronomers give for their measurements is something like three or four times that value. I don't remember the exact value.

QUESTION: I want to go back.

Is the last signal you will send to Mariner 2 to shift it into the cruise mode? That will be the last signal sent?

PICKERING: We will send a signal to put it back into the cruise mode. But that is not necessarily the last. We can keep on sending commands to it of various kinds. There are obviously a limited number of things you can ask it to do. This is the next planned signal, to put it into cruise.

QUESTION: It is not necessarily the last?

PICKERING: No, not necessarily.

QUESTION: Would you satisfy my curiosity: Which took longer to receive, the signals from Pasadena to Washington, or the signals from Mariner to Goldstone?

PICKERING: The signals from Mariner to Goldstone took about 3-1/2 minutes. The signals from Pasadena to Washington I think took a fraction of a second.

As a matter of fact, if one wants to think about the scale of this distance, you realize that at the velocity of light you go around 7-1/2 times around the world a second. Out to Mariner now takes about three and a half minutes.

QUESTION: Dr. Pickering, this question may have been asked while I was out. Can you tell us now at what time today you will be able to give us an exact distance of the closest approach?

PICKERING: No, I am sorry I can't give you that. I know that they will try to get it out of Pasadena as soon as they can. But we have got to allow time for the data to be analyzed.

QUESTION: Do you think it will be available today, sir?

PICKERING: I rather doubt if it will be today. At least late this evening, perhaps.

QUESTION: Dr. Pickering, can you compare this American accomplishment with the Russian Mars attempt in terms of relative difficulty and the amount the Russians may learn about Mars in relation to what we have learned?

PICKERING: Yes. The relative Russian attempts to the planets, the Russians launched a Venus probe at the last opportunity, in February of 1961. They lost communications with that probe a few days after launching. The description of the probe was of a spacecraft somewhat larger than Mariner, but having some resemblance, conceptual resemblance at least, to our spacecraft.

The Mars probe is reportedly a considerably heavier probe than ours, with a reported weight of about 2,000 pounds. I have seen very little data published as to what sorts of signals are being received, or what the quality of the signals may be. In order to come anywhere reasonably close to the planet Mars, a mid-course maneuver will have to be effected by this time. I don't know whether the Russians have reported such a mid-course maneuver. I have seen no report.

When the Mars probe gets near the planet, apparently the plan is to have it take photographs similar to the photographs which were taken by Lunik III. These will then be developed and scanned by an electrical facsimile system to send the signals back to the Earth.

I saw one report which said that this transmission back to the Earth would occur after the probe had passed the planet and had returned to the general vicinity of the Earth. If this is the plan, it will be probably a year or a year and a half before the probe comes back near the Earth.

WEBB: Gentlemen, we have been here a long time. We have no desire to cut this short. I think it might be well to say that anybody who has to go, or wants to go, certainly ought to feel perfectly free to do so. I know it is your prerogative to close this conference. Those of us like Dr. Newell, Dr. Pickering and others will be here for another period of time for those who want to stay. But in looking around I am sort of impressed that maybe some people don't want to stay. I think anyone who would like to go certainly ought to feel free to do so. We will stay here long enough to try to answer the questions that those really interested have. So I think any of you ought to feel perfectly free to go.

QUESTION: Mr. Webb, am I correct, have you received any communications in the last hour from your Russian counterparts, words of congratulations on this feat, and do you have arrangements to share the data with the Soviets as quickly as possible?

WEBB: On the first question, I am aware of no message that has been received. On the second part, we are sharing here with them, as well as the rest of the world, the total of what we know now. That is, that the probe has passed Venus, that all of the instruments were working correctly.

There will be preliminary reports issued with respect to the data received and there will be published complete scientific analysis of the data. These will be available to the Russians as well as ourselves. This is a policy of the United States space program, as I indicated in my opening statement.

QUESTION: I was going to ask Dr. Pickering a question. He seems to have vanished.

WEBB: He is probably trying to find out what the data is showing.

QUESTION: I have a general question. Can you say how this Venus probe compares with the scientific accomplishment with the flight of John Glenn or any of the other astronauts?

WEBB: Let's let Dr. Newell, our Manager of Space Sciences for the whole United States program, answer that, if he wishes. He has been one of the strong advocates of manned space flight as well as a space science program.

NEWELL; I don't know whether to say thank you for that one, Jim, or not.

I don't believe that you can compare the two. They are both firsts, they are both significant, they are both tremendous engineering accomplishments.

WEBB: One is "first" for us.

NEWELL: You are right. You are right. They are both tremendous engineering accomplishments. The John Glenn flight is laying the groundwork for future science by men in space, and now, of course, my interests as a scientist are showing.

The measurements on Venus are laying the groundwork for future more detailed analysis of what this mystery planet is like.

As you well know, we want to send instruments to the planet to learn more about it, and before we can make the spacecraft to land on the surface, we have got to know whether the temperatures really are the temperatures that melt lead. If they are, the kind of spacecraft we have to build is going to be an interesting and difficult one.

WEBB: Homer, don't you want to also add that the Space Science Board, you as the head of our science program, all have clearly indicated that the areas of science, of scientific exploration, of the phenomena of the Universe, a more clear definition of the environment, can only be completed as Man goes out to participate in the observations and helps suggest the measuring instruments to record the phenomena? I think this may have been part of the question.

Could you do this with instruments of the Mariner type? How much more can you get with Man, or think you can get?

NEWELL: That was the point I was trying to make when I said that the John Glenn flight is laying the groundwork for manned science in space. There is a tremendous amount that Man will have to do when, for example, you get on the Moon. There is a tremendous amount that Man eventually will have to do in studying the planets, just as he had to do in studying the Earth here.

I think one forgets that we have been investigating the Earth now for centuries, and Man has been the principal instrument in this investigation of the Earth.

At a distance from Venus of 36,000,000 miles, we have to use instruments now because we can't send men there. But eventually, when we can send a man there, we will begin to apply to the study of the planet the techniques and the thinking and the discernment that we now apply to studying the Earth at home here.

MITTAUER: Dr. Pickering has some additional word, and we will have time for about two more questions.

PICKERING: I thought you might be interested that Pasadena just told me that the cruise mode signal was sent. It is on its way out. It will take six minutes for it to get out and back and say "Yes, we are back in the cruise mode". So a minute or two from now I hope that we will get the word that it has been turned back on to the cruise mode.

Also, the current estimate of the moment of closest approach to Venus was about ten seconds before 3 o'clock.

QUESTION: At the estimated distance of 21,100 miles?

PICKERING: The distance estimate will go up a little, to about probably 21,500 or 21,600, something of that sort. I would like you to regard that as a very preliminary estimate.

I will make this comment: The estimated closest approach is very close to the original estimate of 21,000.

QUESTION: Dr. Pickering, what kind of experiments were you planning to add to the Venus '64 fly-by, can you tell us?

PICKERING: This question concerns additional experiments of Venus '64.

No, I don't think I want to comment about this except to just sort of make the obvious remark that various refinements of radiometer type measurements will be the sort of things which will probably be the key measurements.

In other words, we do not visualize television-type measurements at this time, because, as was said earlier, you can not see the surface of Venus; all you see is clouds. And getting a television picture of the tops of clouds wouldn't be very exciting.

When it comes to the Mars probe, then it makes more sense to talk about television types of pictures.

But for the Venus measurements, we will deal more with the radiometer class of instruments.

QUESTION: I would like to ask Mr. Webb whether he can give us any information regarding our knowledge of the current status of the Soviet Mars probe. Do we know whether it is transmitting, do we know whether it is on proper trajectory, do we know whether the Russians have effected a mid-course maneuver?

WEBB: I am not sure that I can give you any very good information. I have heard a number of reports. I would want to consult some of my colleages here to see exactly what might be said, if we were going to say anything.

I think it is a pretty safe bet to rely on what they announced publicly about these kinds of activities until we know something different. I mean by that, that what they actually say has been a lot more reliable than perhaps what they have not said, and I think I pointed that out in the release we made with respect to their failures in their planetary program.

I believe that is all that I can say at this time.

As I mentioned earlier, we are not anxious to close this off. I did want to say one thing about this press conference. Having been here now 22-1/2 months, approximately, it seems to me it is rather remarkable that in every other press conference we have had about space feats, particularly those involving manned space flight, we have had tremendous emphasis, interest, questions on the booster, the capability of rockets, and the tense moments when the performance of the rocket was in some question, or at least our emotions were very much involved.

It is rather interesting here that we passed very briefly over the rather tremendous accomplishment of having the boost capability and precise control that permitted us not only to go out with the big booster to restart the Agena and make the injection, but then to fire up another very small thrust that could change the speed of this vehicle so as to change the actual approach to Venus from about 225,000 miles to something on the order of 21,000 miles.

This indicates, I think, that we are moving into a period when people are going to be much more interested in what the payloads are out to accomplish than they are the specifics of the boost capacity that makes them possible.

Perhaps this is a bit of a milestone in that regard, as well as the scientific data being received, because the space program is not designed to just fly boosters. It is designed to use the boosters to do work in space.

Are we near the end?

MITTAUER: I believe that concludes it. I see no hands raising.

Thank you very much, Gentlemen.

(Whereupon, at 3:47 p.m., the conference was concluded.)

APPENDIX B

SUBCONTRACTORS

The Mariner Project is part of the National Aeronautics and Space Administration's lunar and planetary space exploration program. The Jet Propulsion Laboratory of California Institute of Technology, under contract to NASA, had the responsibility for project management.

Thirty-four subcontractors to JPL provided instruments and other hardware for Mariners 1 and 2. These contracts amounted to $6, 500, 000.

The subcontractors were:

Aeroflex Corporation Long Island City, New York	Jet vane actuators
American Electronics, Inc. Fullerton, California	Transformer-rectifiers for flight telecommunications
Ampex Corporation Instrumentation Division Redwood City, California	Tape recorders for ground telemetry and data handling equipment
Applied Development Corporation Monterey Park, California	Decommutators and teletype encoders for ground telemetry equipment
Astrodata, Inc. Anaheim, California	Time code translators, time code generators, and spacecraft signal simulators for ground telemetry equipment
Barnes Engineering Company Stamford, Connecticut	Infrared radiometers Planet simulator
Bell Aerospace Corporation Bell Aerosystems Division Cleveland, Ohio	Accelerometers and associated electronic modules
Computer Control Company, Inc. Framingham, Massachusetts	Data conditioning systems
Conax Corporation Buffalo, New York	Midcourse propulsion explosive valves Squibs
Consolidated Electrodynamics Corp. Pasadena, California	Oscillographs for data reduction
Consolidated Systems Corporation Monrovia, California	Scientific instruments Operational support equipment

Dynamics Instrumentation Company Monterey Park, California	Isolation amplifiers for telemetry Operational support equipment
Electric Storage Battery Company Missile Battery Division Raleigh, North Carolina	Spacecraft batteries
Electro-Optical Systems, Inc. Pasadena, California	Spacecraft power conversion equipment
Fargo Rubber Corporation Los Angeles, California	Midcourse propulsion fuel tank bladders
Glentronics, Inc. Glendora, California	Power supplies for data conditioning system
Groen Associates Sun Valley, California	Actuators for solar panels
Houston Fearless Corporation Torrance, California	Pin pullers
Kearfott Division General Precision, Inc. Los Angeles, California	Gyroscopes
Marshall Laboratories Torrance, California	Magnetometers and associated operational support equipment
Matrix Research and Development Corporation Nashua, New Hampshire	Power supplies for particle flux detectors
Menasco Manufacturing Company Burbank, California	Midcourse propulsion fuel tanks and nitrogen tanks
Midwestern Instruments Tulsa, Oklahoma	Oscillographs for data reduction
Mincom Division Minnesota Mining & Manufacturing Los Angeles, California	Tape recorders for ground telemetry and data handling equipment
Motorola, Inc. Military Electronics Division Scottsdale, Arizona	Spacecraft command subsystems, transponders, and associated operational support equipment
Nortronics Division of Northrup Corporation Palos Verdes Estates, California	Attitude control gyro electronic, autopilot electronic, and antenna servo electronic modules, long-range Earth sensors and Sun sensors
Ransom Research Division of Wyle Laboratories San Pedro, California	Verification and ground command modulation equipment
Rantec Corporation Calabasas, California	Transponder circulators and monitors

Ryan Aeronautical Company Aerospace Division San Diego, California	Solar panel structures
Spectrolab Division of Textron Electronics, Inc. North Hollywood, California	Solar cells and their installation and electrical connection on solar panels
State University of Iowa Iowa City, Iowa	Calibrated geiger counters
Sterer Engineering & Manufacturing Company North Hollywood, California	Valves and regulators for midcourse propulsion and attitude control systems
Texas Instruments, Inc. Apparatus Division Dallas, Texas	Spacecraft data encoders and associated operational support equipment, ground telemetry demodulators
Trans-Sonic, Inc. Burlington, Massachusetts	Transducers

In addition to these subcontractors, over 1,000 other industrial firms contributed to the Mariner Project. These procurements amounted to over $3,500,000.